CHAPTER 6

Protein: Amino Acids

People commonly associate protein with strength and meat with protein. Consequently, they eat steak to build their muscles, but their thinking is only partly correct. Protein is a vital structural and working substance in all cells, not just muscle cells. Meat is a good source of protein, but so are milk, eggs, legumes, and many grains and vegetables. People who overvalue protein may overemphasize meat in their diets, sometimes at the expense of other, equally important nutrients and foods. Protein is important, but it is only one of the nutrients needed to maintain the body's health.

The Chemist's View of Proteins

Chemically, proteins contain the same atoms as carbohydrates and lipids—carbon (C), hydrogen (H), and oxygen (O)—but proteins also contain nitrogen (N) atoms. These nitrogen atoms give the name *amino* (nitrogen containing) to the amino acids—the links in the chains of proteins. Also, proteins assume extraordinary and unique shapes, which enable them to play their vital roles in the body.

proteins: compounds composed of carbon, hydrogen, oxygen, and nitrogen atoms, arranged into amino acids linked in a chain. Some amino acids also contain sulfur atoms.

Amino Acids

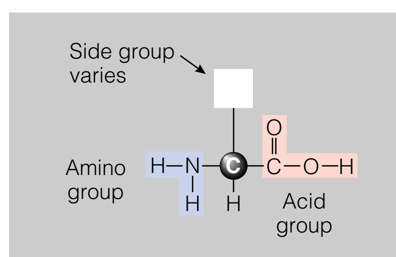
All amino acids have the same basic structure—a central carbon (C) atom with a hydrogen (H), an amino group (NH_2), and an acid group (COOH) attached to it. Carbon atoms need to form four bonds, though, so a fourth attachment is necessary, and it is this fourth site that distinguishes each amino acid from the others. Attached to the carbon atom at the fourth bond is a distinct atom, or group of atoms, known as the *side group* or *side chain* (see Figure 6-1).

amino (a-MEEN-oh) **acids:** building blocks of proteins; each contains an amino group, an acid group, a hydrogen atom, and a distinctive side group, all attached to a central carbon atom.
- **amino** = containing nitrogen

Reminder:
- H forms 1 bond.
- O forms 2 bonds.
- N forms 3 bonds.
- C forms 4 bonds.

Figure 6-1
Amino Acid Structure

All amino acids have a carbon (known as the alpha-carbon), with an amino group (NH_2), an acid group (COOH), a hydrogen (H), and a side group attached. The side group is a unique chemical structure that differentiates one amino acid from another.



• ***Unique Side Groups*** • The side groups on amino acids vary from one amino acid to the next, making proteins more complex than either carbohydrates or lipids. A polysaccharide (starch, for example) may be several thousand units long, but every unit is a glucose molecule just like all the others. A protein, on the other hand, is made up of about 20 different amino acids, each with a different side group. Table 6-1 lists the amino acids most common in proteins.*

The simplest amino acid, glycine, has a hydrogen atom as its side group. A slightly more complex amino acid, alanine, has an extra carbon with three hydrogen atoms. Other amino acids have more complex side groups (see Figure 6-2 on p. 162 for examples). Thus, although all amino acids share a common structure, they differ in size, shape, electrical charge, and other characteristics because of differences in these side groups.

• ***Nonessential Amino Acids*** • The body can synthesize more than half of the amino acids for itself, if it is given nitrogen to form the amino group and fragments from carbohydrate and fat to form the rest of the structure. Proteins in foods usually deliver these amino acids, but it is not essential that they do so.

• ***Essential Amino Acids*** • There are nine amino acids that the human body either cannot make at all or cannot make in sufficient quantity to meet its needs. These nine amino acids must be supplied by the diet; they are essential.

essential amino acids: amino acids that the body cannot synthesize in amounts sufficient to meet physiological needs (see Table 6-1). Some researchers refer to essential amino acids as **indispensable** and to nonessential amino acids as **dispensable.**

*Some amino acids occur in related forms (for example, proline can acquire an OH group to become hydroxyproline). Besides the 20 common amino acids, which can all be components of proteins, others occur individually (for example, taurine and ornithine), and still others can be made by chemists.

Table 6-1
Amino Acids

Proteins are made up of about 20 common amino acids. The first column lists the *essential* amino acids for human beings (those the body cannot make—that must be provided in the diet).

Essential Amino Acids		Nonessential Amino Acids	
Histidine	(HISS-tuh-deen)	Alanine	(AL-ah-neen)
Isoleucine	(eye-so-LOO-seen)	Arginine	(ARJ-ih-neen)
Leucine	(LOO-seen)	Asparagine	(ah-SPAR-ah-geen)
Lysine	(LYE-seen)	Aspartic acid	(ah-SPAR-tic acid)
Methionine	(meh-THIGH-oh-neen)	Cysteine	(SIS-teh-een)
Phenylalanine	(fen-il-AL-ah-neen)	Glutamic acid	(GLU-tam-ic acid)
Threonine	(THREE-oh-neen)	Glutamine	(GLU-tah-meen)
Tryptophan	(TRIP-toe-fan, TRIP-toe-fane)	Glycine	(GLY-seen)
		Proline	(PRO-leen)
Valine	(VAY-leen)	Serine	(SEER-een)
		Tyrosine	(TIE-roe-seen)

NOTE: In special cases, some nonessential amino acids may become conditionally essential (see the text).

conditionally essential amino acid: an amino acid that is normally nonessential, but must be supplied by the diet in special circumstances when the need for it exceeds the body's ability to produce it.

• ***Conditionally Essential Amino Acids*** • Sometimes a nonessential amino acid becomes essential under special circumstances. For example, the body normally makes tyrosine (a nonessential amino acid) from the essential amino acid phenylalanine. But if the diet fails to supply enough phenylalanine, or if the body cannot make the conversion for some reason (as happens in the inherited disease phenylketonuria), then tyrosine becomes *conditionally* essential. Similarly, glutamine, the most abundant amino acid in the body, becomes conditionally essential in advanced liver disease.[1]

Proteins

peptide bond: a bond that connects the acid end of one amino acid with the amino end of another, forming a link in a protein chain.

dipeptide (dye-PEP-tide): two amino acids bonded together.
- **di** = two
- **peptide** = amino acid

tripeptide: three amino acids bonded together.
- **tri** = three

polypeptide: many (ten or more) amino acids bonded together. An intermediate string of four to nine amino acids is an **oligopeptide** (OL-ee-go-PEP-tide).
- **poly** = many
- **oligo** = few

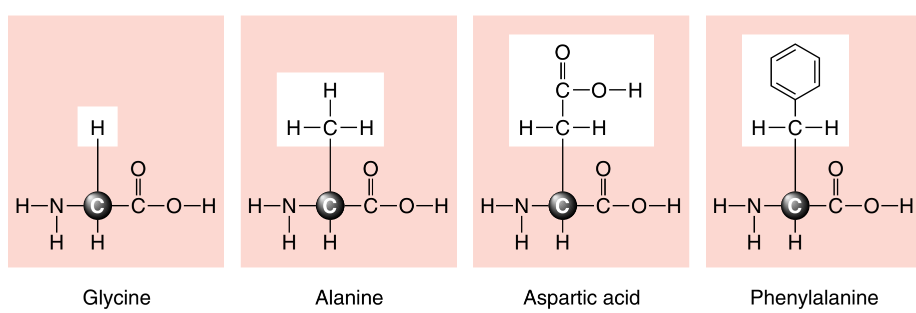
Cells link amino acids end-to-end in a virtually infinite variety of sequences to form thousands of different proteins. Each amino acid is connected to the next by a peptide bond.

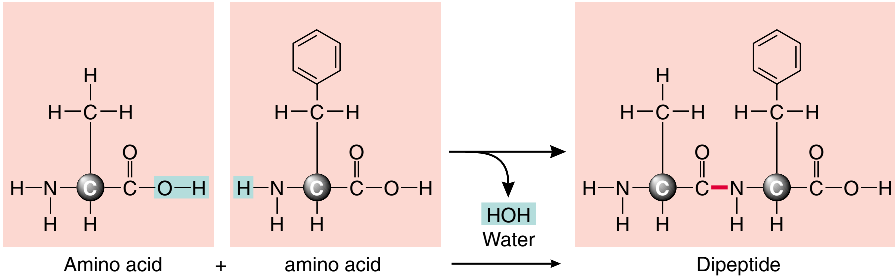
• ***Amino Acid Chains*** • Condensation reactions create the bonds between amino acids, just as they combine monosaccharides to form disaccharides, and fatty acids with glycerol to form triglycerides.* Two amino acids bonded together form a dipeptide (see Figure 6-3). By another such reaction, a third amino acid can be added to the chain to form a tripeptide. As additional amino acids join the chain, a polypeptide is formed. Most proteins are a few dozen to several hundred amino acids long. Figure 6-4 provides an example—insulin.

*Later in the chapter, Figure 6-6 shows how each protein's sequence is dictated by the genetic code in DNA, and the text describes how the sequence shapes the protein.

Figure 6-2
Examples of Amino Acids

Note that all amino acids have a common chemical structure but that each has a different side group. Appendix C presents the chemical structures of the 20 amino acids most common in proteins.





An OH group from the acid end of one amino acid and an H atom from the amino group of another join to form a molecule of water.

A peptide bond (highlighted in red) forms between the two amino acids, creating a dipeptide.

Figure 6-3

Condensation of Two Amino Acids to Form a Dipeptide

• ***Amino Acid Sequences*** • If a person could walk along a carbohydrate molecule like starch, the first stepping stone would be a glucose. The next stepping stone would also be a glucose, and it would be followed by a glucose, and yet another glucose. But if a person were to walk along a polypeptide chain, each stepping stone would be one of 20-odd different amino acids. The first stepping stone might be the amino acid methionine. The second might be an alanine. The third might be a glycine, and the fourth a tryptophan, and so on. Walking along another polypeptide path, a person might step on a phenylalanine, then a valine, and a glutamine. In other words, amino acid sequences within proteins vary.

The amino acids can act somewhat like the letters in an alphabet. If you had only the letter *G*, all you could write would be a string of Gs: G–G–G–G–G–G–G. But with 20 different letters available, you could create poems, songs, or novels. The 20 amino acids can be linked together in an even greater variety of sequences than are possible for letters in a word or words in a sentence. Thus the variety of possible sequences for polypeptide chains is tremendous.

• ***Protein Shapes*** • Polypeptide chains twist into a variety of complex, tangled shapes, depending on their amino acid sequences. Each amino acid has a unique chemical character that attracts it to, or repels it from, the surrounding fluids and other amino acids. Some amino acid side chains carry electrical charges that are attracted to water molecules (they are hydrophilic). Other side chains are neutral and are repelled by water (they are hydrophobic). As amino acids are strung together to make a polypeptide, the chain folds so that its charged hydrophilic side chains are on the outer surface near water; the neutral hydrophobic groups tuck themselves inside, away from water. The intricate, coiled shape the polypeptide finally assumes gives it maximum stability in the body's watery fluids.

• ***Protein Functions*** • The different shapes of proteins enable them to perform various tasks in the body. Some form hollow balls that can carry and store materials within them, and some, such as those of tendons, are more than ten times as long as they are wide, forming strong, rodlike structures. Some polypeptides are functioning proteins as they are; others need to associate with other polypeptides to form larger working complexes. Some proteins require minerals to activate them. One molecule of hemoglobin—the large, globular protein molecule that, by the billions, packs the red blood cells and carries oxygen—is made of four associated polypeptide chains, each holding the mineral iron. Figure 6-4 shows the two chains of insulin.

• ***Protein Denaturation*** • When proteins are subjected to heat, acid, or other conditions that disturb their stability, they undergo denaturation—that is, they uncoil and lose their shapes and, consequently, their functions. Past a certain point, denaturation is

The shape of a protein depends on the sequence of its amino acids, the bonds linking the amino acids, and the interactions of the side chains with each other and with the surrounding molecules.

hemoglobin (HE-moh-GLOW-bin): the globular protein of the red blood cells that carries oxygen from the lungs to the cells throughout the body.

- **hemo** = blood
- **globin** = globular protein

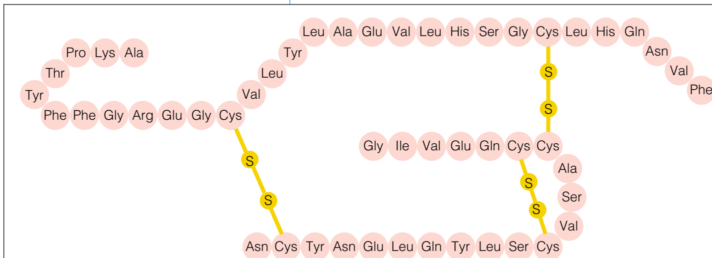


Figure 6-4

Amino Acid Sequence of Human Insulin

Human insulin is a relatively small protein that consists of 51 amino acids in two short polypeptide chains. (For amino acid abbreviations, see Appendix C.) Two bridges link the two chains. A third bridge spans a section within the short chain.

Known as disulfide bridges, these links always involve the amino acid cysteine (Cys), whose side group contains sulfur (S). Cysteines connect to each other when bonds form between these side groups.

denaturation (dee-NAY-chur-AY-shun): the change in a protein's shape brought about by heat, acid, base, alcohol, heavy metals, or other agents.

irreversible. Familiar examples of denaturation include the hardening of an egg when it is cooked, the curdling of milk when acid is added, and the stiffening of egg whites when they are whipped.

IN SUMMARY

Chemically speaking, proteins are more complex than carbohydrates or lipids, being made of some 20 different amino acids, 9 of which the body cannot make (they are essential). Each amino acid contains an amino group, an acid group, a hydrogen atom, and a distinctive side group. Cells link amino acids together in a series of condensation reactions to create proteins. The distinctive sequence of amino acids in each protein determines its unique shape and function.

Digestion and Absorption of Protein

Proteins in foods do not become body proteins, but supply the amino acids from which the body makes its own proteins. When a person eats foods containing protein, enzymes break the long polypeptide strands into shorter strands, the short strands into tripeptides and dipeptides, and, finally, the tripeptides and dipeptides into amino acids.

The Process of Digestion

Figure 6-5 illustrates the digestion of protein through the GI tract. Proteins are crushed and moistened in the mouth, but the real action begins in the stomach.

The inactive form of an enzyme is called a **proenzyme.**
- **pro** = before

pepsin: a gastric protease. Pepsin is secreted in an inactive form, **pepsinogen,** which is activated by hydrochloric acid in the stomach.

Reminder: An enzyme that hydrolyzes protein is a *protease* (PRO-tee-ace).

• *In the Stomach* • In the stomach, hydrochloric acid uncoils (denatures) each protein's tangled strands so that digestive enzymes can attack the peptide bonds. The hydrochloric acid also converts the inactive form of the enzyme pepsinogen to its active form, pepsin. Pepsin cleaves proteins—large polypeptides—into smaller polypeptides and some amino acids.

• *In the Small Intestine* • When polypeptides enter the small intestine, pancreatic and intestinal proteases hydrolyze them further into short peptide chains (oligopeptides), tripeptides, dipeptides, and amino acids. Figure 6-5 includes the details of digestive enzyme action for dietary protein. A number of distinct carriers transport these protein pieces into the intestinal cells.

The Process of Absorption

peptidase: a digestive enzyme that hydrolyzes peptide bonds. *Tripeptidases* cleave tripeptides; *dipeptidases* cleave dipeptides. *Endopeptidases* cleave peptide bonds *within* the chain to create smaller fragments, whereas *exopeptidases* cleave bonds at the *ends* to release free amino acids.
- **tri** = three
- **di** = two
- **endo** = within
- **exo** = outside

The cells of the small intestine absorb amino acids and have peptidase enzymes on their surfaces that split most of the dipeptides and tripeptides into single amino acids. A few dipeptides, tripeptides, and even larger molecules sometimes escape digestion and cross the digestive tract wall to enter the bloodstream.

Some nutrition faddists fail to realize that most proteins are broken down to amino acids before absorption. They urge consumers to "Eat enzyme A. It will help you digest your food." Or "Don't eat food B. It contains enzyme C, which will digest cells in your body." In reality, though, enzymes in foods are digested, just as all proteins are. Only the digestive enzymes, whose design prevents them from being denatured or digested, can work in such an environment.

Another misconception is that eating predigested proteins (amino acid supplements) saves the body from having to digest proteins and keeps the digestive system from "overworking." Such a belief grossly underestimates the body's abil-

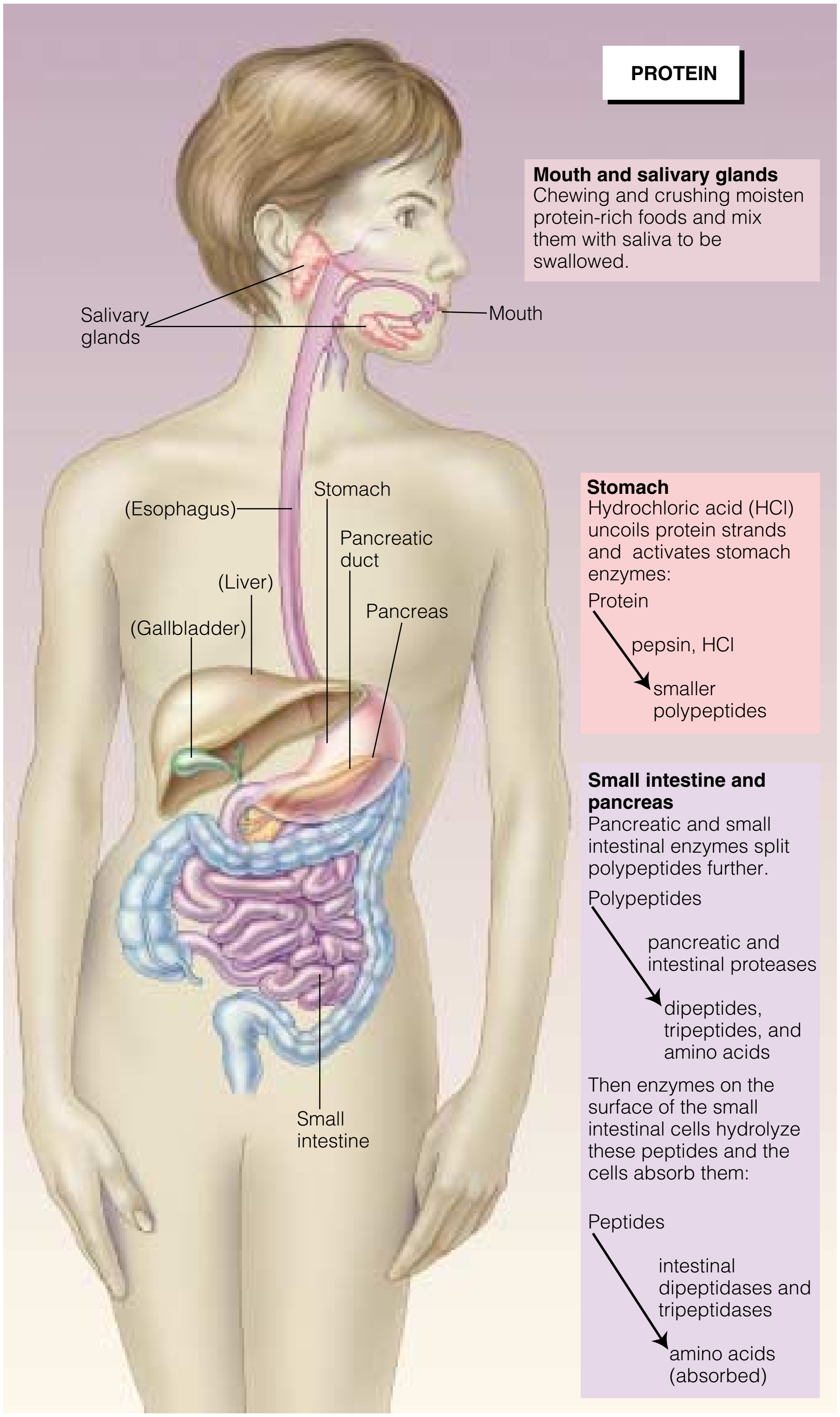


Figure 6-5

Protein Digestion in the GI Tract

In the Stomach:

Hydrochloric acid (HCl)

- Denatures protein structure.
- Activates pepsinogen to pepsin.

Pepsin

- Cleaves proteins to smaller polypeptides and some free amino acids.
- Inhibits pepsinogen synthesis.

In the Small Intestine:

Enteropeptidase[a]

- Converts pancreatic trypsinogen to trypsin.

Trypsin

- Inhibits trypsinogen synthesis.
- Cleaves peptide bonds next to the amino acids lysine and arginine.
- Converts pancreatic procarboxypeptidases to carboxypeptidases.
- Converts pancreatic chymotrypsinogen to chymotrypsin.

Chymotrypsin

- Cleaves peptide bonds next to the amino acids phenylalanine, tyrosine, tryptophan, methionine, asparagine, and histidine.

Carboxypeptidases

- Cleave amino acids from the acid (carboxyl) ends of polypeptides.

Elastase and collagenase

- Cleave polypeptides into smaller polypeptides and tripeptides.

Aminopeptidases

- Cleave amino acids from the amino ends of small polypeptides (oligopeptides).

Tripeptidases

- Cleave tripeptides to dipeptides and amino acids.

[a]Enteropeptidase was formerly known as *enterokinase.*

ities. As a matter of fact, the digestive system handles whole proteins *better* than predigested ones because it dismantles and absorbs the amino acids at rates that are optimal for the body's use. (The last section of this chapter discusses amino acid supplements further.)

IN SUMMARY

Via digestion facilitated mostly by the stomach's acid and enzymes, the body first denatures dietary proteins, then cleaves them into polypeptides, then oligo-, tri-, and dipeptides, and some amino acids. Intestinal enzymes split these further, mostly to single amino acids. Then carriers in the membranes of intestinal cells transport the amino acids into the cells, where they are released into the bloodstream.

Proteins in the Body

The human body contains an estimated 10,000 to 50,000 different kinds of proteins. Of these, about 1000 have been studied. Only about 10 are described in this chapter—but these should be enough to illustrate proteins' versatility, uniqueness, and importance. As you will see, each protein has a specific function and that function is determined during protein synthesis.

Growing children end each day with more bone, blood, muscle, and skin cells than they had at the beginning of the day.

Protein Synthesis

Each human being is unique because of minute differences in the body's proteins. These differences are determined by the amino acid sequences of proteins, which, in turn, are determined by genetics. The following paragraphs describe in words the ways cells synthesize proteins; Figure 6-6 provides a pictorial description.

The instructions for making every protein in a person's body are transmitted by way of the genetic information received at conception. This body of knowledge, which is filed in the DNA within the nucleus of every cell, never leaves the nucleus.

• ***Delivering the Instructions*** • To inform a cell of the sequence of amino acids for a needed protein, a stretch of DNA serves as a template for making a strand of RNA that carries a code, listing in order the amino acids that will be needed to make a given protein. Known as messenger RNA, this molecule escapes through the nuclear membrane. Messenger RNA seeks out and attaches itself to one of the ribosomes (a protein-making machine, which is itself composed of RNA and protein). Thus situated, messenger RNA presents its list, specifying the sequence in which the amino acids are to line up to make a strand of protein.

• ***Lining Up the Amino Acids*** • Other forms of RNA, called transfer RNA, collect amino acids from the cell fluid and bring them to the messenger. Each of the 20 amino acids has a specific transfer RNA. Thousands of transfer RNA, each carrying its amino acid, cluster around the ribosomes, awaiting their turn to unload. When the messenger's list calls for a specific amino acid, the transfer RNA carrying that amino acid moves into position. Then the next loaded transfer RNA moves into place and then the next and the next. Thus the amino acids line up in the sequence that is called for, and enzymes bind them together. Finally, the completed protein strand is released, the messenger is degraded, and the transfer RNA are freed to return for another load of amino acids.

• ***Sequencing Errors*** • The sequence of amino acids in each protein determines its configuration, which supports a specific function. If a genetic error alters the amino acid sequence of a protein, or if a mistake is made in copying the sequence,

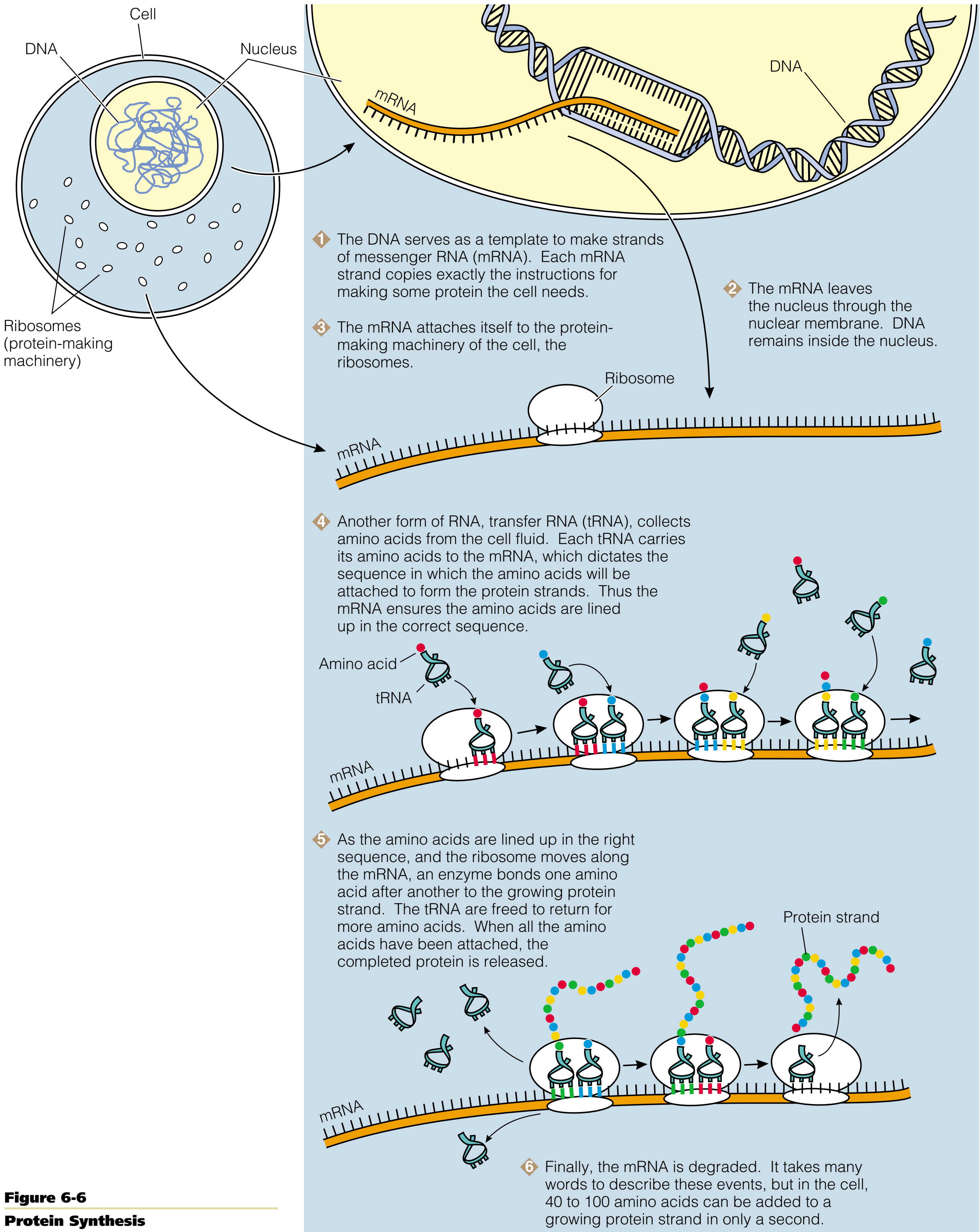


Figure 6-6
Protein Synthesis

an altered protein will result, sometimes with dramatic consequences. The protein hemoglobin offers one example of such a genetic variation. In a person with sickle-cell anemia, two of hemoglobin's four polypeptide chains (described earlier on p. 163) have the normal sequence of amino acids, but the other two chains do not—they have the amino acid valine in a position that is normally occupied by glutamic acid (see Figure 6-7). This single alteration in the amino acid sequence changes the character and shape of the protein so much that hemoglobin loses its ability to carry oxygen effectively.[2] The red blood cells filled with this abnormal hemoglobin stiffen into elongated sickle, or crescent, shapes instead of maintaining their normal pliable disc shape—hence the name, sickle-cell anemia. Sickle-cell anemia causes many medical problems and can be fatal. Caring for children with sickle-cell anemia includes diligent attention to their water needs; dehydration can trigger a crisis.[3]

• ***Nutrients and Gene Expression*** • When a cell makes a protein as described earlier, scientists say that the gene for that protein has been "expressed." Cells can regulate gene expression to make the type of protein, in the amounts and at the rate, they need. Nearly all of the body's cells possess the genes for making all human proteins, but each type of cell makes only the proteins it needs. For example, only cells of the pancreas express the gene for insulin; in other cells, that gene is idle. Similarly, the cells of the pancreas do not make the protein hemoglobin, which is needed only by the red blood cells.

Recent research has unveiled some of the fascinating ways nutrients regulate gene expression and protein synthesis. These discoveries have begun to explain some of the relationships between nutrients, genes, and disease development. The benefits of polyunsaturated fatty acids in defending against heart disease, for example, are partially explained by their role in influencing gene expression for lipid enzymes. Later chapters provide additional examples of how nutrients influence gene expression.

IN SUMMARY

Cells synthesize proteins according to the genetic information provided by the DNA in the nucleus of each cell. This information dictates the order in which amino acids must be linked together to form a given protein. Sequencing errors occasionally occur, sometimes with significant consequences.

Roles of Proteins

Whenever the body is growing, repairing, or replacing tissue, proteins are involved. Sometimes their role is to facilitate or to regulate; other times it is to become part of a structure. Yes, versatility is a key feature of proteins.

• ***As Building Materials*** • From the moment of conception, proteins form the building blocks of most body structures. For example, to build a bone or a tooth, cells first lay down a matrix of the protein collagen and then fill it with crystals of calcium, phosphorus, magnesium, fluoride, and other minerals.

The protein collagen is also the material of ligaments and tendons and the strengthening glue between the cells of the artery walls that enables the arteries to withstand the pressure of the blood surging through them with each heartbeat. Also made of collagen are scars that knit the separated parts of torn tissues together.

As old skin cells fall off, new cells made largely of protein grow from underneath to compensate. Cells in the deeper skin layers synthesize new proteins to go into hair and fingernails. GI tract cells are replaced every three days. Both inside and outside, then, the body constantly deposits protein into new cells that replace those that have been lost.

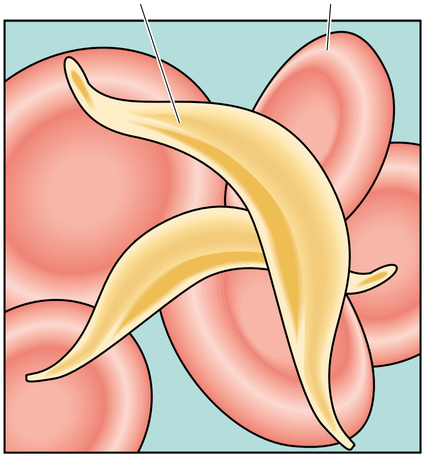
sickle-cell anemia: a hereditary form of anemia characterized by abnormal sickle- or crescent-shaped red blood cells. Sickled cells interfere with oxygen transport and blood flow. Symptoms include hemolytic anemia (red blood cells burst), fever, and severe pain in the joints and abdomen; they are precipitated by dehydration and insufficient oxygen (as may occur at high altitudes).

Note: Anemia is not a disease, but a symptom of various diseases. In the case of sickle-cell anemia, a defect in the hemoglobin molecule changes the shape of the red blood cells. Later chapters describe how vitamin and mineral deficiencies change the size and color of the red blood cells. In all cases, the abnormal blood cells are unable to meet the body's oxygen demands.

Figure 6-7

Normal Red Blood Cells Compared with Sickle Cells

Normally, red blood cells are disc-shaped; in the inherited disorder sickle-cell anemia, red blood cells are sickle- or crescent-shaped. This alteration in shape occurs because valine replaces glutamic acid in the amino acid sequence of hemoglobin's polypeptide chain. As a result of this one amino acid's being in the wrong place, the hemoglobin has a diminished capacity to carry oxygen.



Amino acid sequence of normal hemoglobin:
Val–His–Leu–Thr–Pro–Glu–Glu

Amino acid sequence of sickle-cell hemoglobin:
Val–His–Leu–Thr–Pro–Val–Glu

matrix (MAY-tricks): the basic substance that gives form to a developing structure; in the body, the formative *cells* from which teeth and bones grow.

collagen (KOL-ah-jen): the protein material from which connective tissues such as scars, tendons, ligaments, and the foundations of bones and teeth are made.

• ***As Enzymes*** • Digestive enzymes have appeared in every chapter since Chapter 3, but digestion is only one of the many processes enzymes facilitate. Enzymes not only break down substances, they also build substances and transform one substance into another. Figure 6-8 diagrams a synthesis reaction.

An analogy may help to clarify the role of enzymes. Enzymes are comparable to the clergy and judges who make and dissolve marriages. When a minister marries two people, they become a couple, with a new bond between them. They are joined together—but the minister remains unchanged. The minister represents synthetase enzymes that make large compounds from smaller ones. One minister can perform thousands of marriage ceremonies, just as one enzyme can perform billions of synthetic reactions.

Similarly, a judge who lets married couples separate may decree many divorces before retiring or dying. The judge represents enzymes that hydrolyze larger compounds to smaller ones; for example, the digestive enzymes. The point is that, like the minister and the judge, enzymes themselves are not altered by the reactions they facilitate. They are catalysts, permitting reactions to occur more quickly and efficiently than if substances depended on chance encounters alone.

• ***An Example of Enzyme Action*** • The chemical structures in the margin and the paragraphs that follow provide an example of enzyme action. This single biochemical pathway illustrates how one compound encounters an enzyme, is converted to another compound that encounters another enzyme, and so forth until the final product is entirely different from the starting material. The details are offered only to give you insight into the kinds of processes that take place in the daily lives of the body's cells.

In the breakdown of glucose (a 6-carbon compound), enzymes add two phosphate groups, alter the arrangement of the atoms, and then split the molecule in half, leaving two 3-carbon compounds. One of these is compound A and the other is converted to compound A, so the two halves derived from glucose follow the same path from that point on.

Compound A floats around until it encounters an enzyme that recognizes it. This enzyme removes hydrogens from molecules of compound A. Without hydrogens, carbon and oxygen must form a double bond; thus compound B is created. Compound B is released from this enzyme and encounters another enzyme that removes an oxygen and substitutes an amino group in its place; the result is compound C. The next enzyme removes the phosphate group and replaces it with a hydrogen, leaving compound D.

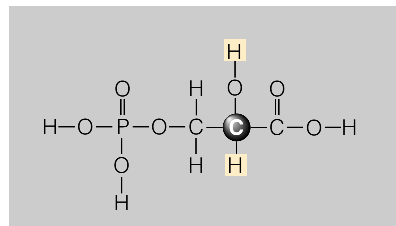
The characteristics of compound D become apparent upon close examination and may not surprise some readers, but this example takes the process one step further before revealing the identity of compound D. Another enzyme, whose function is to remove CH_2OH groups from molecules, forms compound E.

Compound E appeared earlier in this chapter. It has an amino group at one end, an acid group at the other, and a central carbon carrying two hydrogen atoms. It is the amino acid glycine (introduced in Figure 6-2).

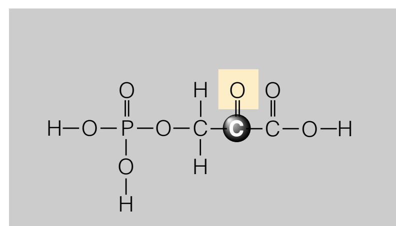
enzymes: proteins that facilitate chemical reactions without being changed in the process; protein catalysts.

synthetase (SIN-the-tase): an enzyme that enables two or more substances to form a more complex structure.

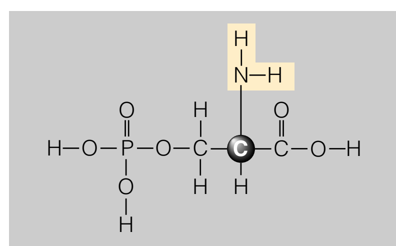
Reminder: A *catalyst* facilitates chemical reactions without itself being changed in the process.



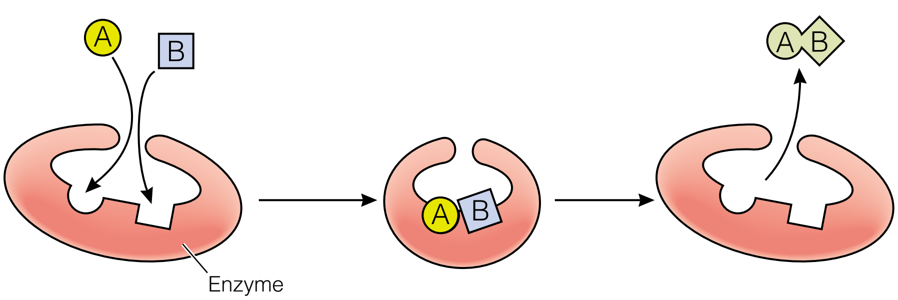
Compound A



Compound B



Compound C



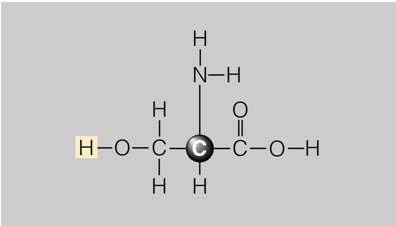
Two separate compounds, A and B, are attracted to the enzyme's active site, making a reaction likely.

The enzyme forms a complex with A and B.

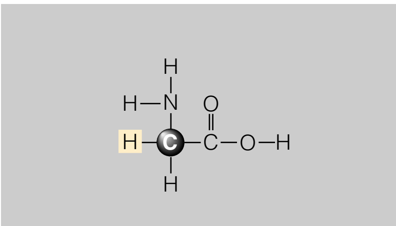
The enzyme is unchanged, but A and B have formed a new compound, AB.

Figure 6-8
Enzyme Action

Each enzyme facilitates a specific chemical reaction. In this diagram, an enzyme enables two compounds to make a more complex structure, but the enzyme itself remains unchanged.



Compound D



Compound E

Amazing! The cellular machinery started with a molecule of glucose (a derivative of dietary carbohydrate), made one small change after another, and transformed it into an amino acid (a member of the protein family). The lesson of this sequence of events is that the body can use glucose and nitrogen-containing compounds to make many of the amino acids needed to build body proteins. The nonessential amino acid glycine is just one example. Compound D, which precedes glycine on the pathway, is another example: the nonessential amino acid serine. Thus, among the thousands of tasks that enzymes perform, they even manufacture many of the nonessential amino acids they themselves are made of.

Perhaps you have realized by now that the protein story is circular. To follow the circle in nutrition, start with a person eating food proteins. The proteins are broken down by proteins (digestive enzymes) into amino acids. The amino acids enter the body cells, where proteins (synthetases) link them into long chains whose sequences are specified by DNA. The chains twist and fold forming proteins, some of which are enzymes. Some enzymes break apart compounds; others put compounds together. Day by day, in billions of reactions, these processes repeat themselves, and life goes on. Only living systems are capable of such self-renewal. A car cannot make another car; a toaster cannot fix another toaster. Only living creatures and the parts they are composed of—the cells—can duplicate and repair themselves.

• ***As Hormones*** • Cells can switch their protein machinery on or off in response to the body's needs. Often hormones do the switching, with marvelous precision. The body's many hormones are messenger molecules, and *some* hormones are proteins. Various glands in the body release hormones in response to changes in the internal environment. The blood carries the hormones to their target tissues, where they elicit the appropriate responses to restore normal conditions.

The hormone insulin provides a familiar example. When blood glucose rises, the pancreas releases its insulin. Insulin stimulates the cells' transport proteins to pump glucose into the cells faster than it can leak out. (After acting on the message, the cells destroy the insulin.) Then, as blood glucose falls, the pancreas reduces its insulin output. Many other proteins act as hormones, maintaining the distribution of hundreds of substances in the body (see Table 6-2).

fluid and electrolyte balance: maintenance of the proper types and amounts of fluid and minerals in each compartment of the body fluids (see also Chapter 12).

Minerals also help regulate fluid distribution; Chapter 12 provides more details.

edema (eh-DEEM-uh): the swelling of body tissue caused by excessive amounts of fluid in the interstitial spaces; seen in protein deficiency (among other conditions).

• ***As Regulators of Fluid and Electrolyte Balance*** • Proteins help to maintain the body's fluid and electrolyte balance. As Figure 6-9 shows, the body's fluids are contained inside the blood vessels (intravascular), within the cells (intracellular), and between the cells (intercellular). Fluids can flow freely between these compartments, but the cells can't move fluids directly. They can manufacture proteins, though. Being large, proteins cannot pass freely across membranes; they are trapped on one side where they attract water. By making and keeping proteins, cells can retain fluids. Similarly, the cells can ship proteins out into the blood and intercellular spaces to maintain the fluid volume there. Should this system fail, too much fluid would collect outside the cells, causing edema.

Proteins help to regulate the composition of body fluids, as well as their quantity. Special transport proteins maintain equilibrium in the surrounding fluids by

Table 6-2

Examples of Hormones and Their Actions

Hormones	Actions
Growth hormone	Promotes growth.
Insulin and glucagon	Regulate blood glucose (see Chapter 4).
Thyroxin	Regulates the body's metabolic rate (see Chapter 8).
Calcitonin and parathormone	Regulate blood calcium (see Chapter 12).
Antidiuretic hormone	Regulates fluid and electrolyte balance (see Chapter 12).

NOTE: *Hormones* are chemical messengers that are secreted by endocrine glands in response to altered conditions in the body. Each travels to one or more specific target tissues or organs, where it elicits a specific response. For descriptions of many hormones important in nutrition, see Appendix A.

moving molecules into and out of cells. Most of these proteins reside in cell membranes and act as "pumps," picking up compounds on one side of the membrane and depositing them on the other. In doing so, transport proteins enable cells to take up and release substances as needed. Each transport protein is specific for a certain compound or group of related compounds. Figure 6-10 illustrates how a membrane-bound transport protein helps to maintain the sodium and potassium concentrations in the fluids inside and outside of cells. The balance of these two electrolytes is critical to neural transmissions and muscle contractions; any disturbance triggers a major medical emergency. Such imbalances can cause irregular heartbeats, muscular weakness, kidney failure, and even death.

• ***As Acid-Base Regulators*** • Proteins also help to maintain the balance between acids and bases within the body fluids. Normal body processes continually produce acids and bases, which the blood carries to the kidneys and lungs for excretion. The challenge is to do this without upsetting the blood's acid-base balance.

In an acid solution, hydrogen ions abound; the more hydrogen ions, the more concentrated the acid. Proteins, which have negative charges on their surfaces, attract hydrogen ions, which have positive charges. By accepting and releasing hydrogen ions, proteins act as buffers, maintaining the acid-base balance of the blood and body fluids.

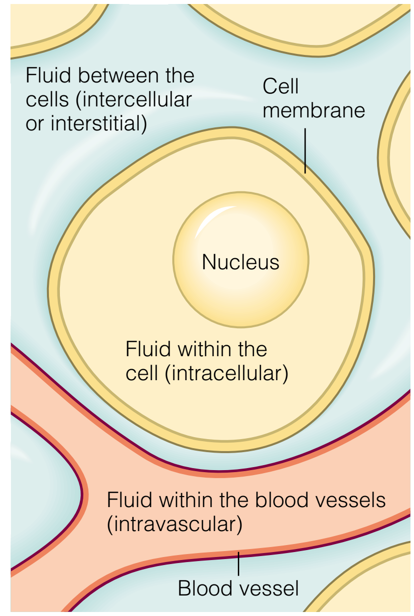
The blood's acid-base balance is tightly controlled. The extremes of acidosis and alkalosis lead to coma and death, largely because they denature working proteins. Disturbing a protein's shape renders it useless. To give just one example, hemoglobin, when denatured, loses its capacity to carry oxygen.

• ***As Transporters*** • Some transport proteins are not attached to membranes, but move about in the body fluids, carrying nutrients and other molecules. The protein hemoglobin carries oxygen from the lungs to the cells. The lipoproteins transport lipids around the body. Special proteins carry vitamins and minerals.

The transport of the mineral iron provides an especially good illustration of these proteins' specificity and precision. When iron enters an intestinal cell, it is captured by a protein that will not let go unless the body needs iron. Before leaving the cell to enter the bloodstream, iron is attached to a carrier protein. The carrier, in turn, can pass iron on to a storage protein in the bone marrow or other tissues, which will hold the iron until it is needed. When it is needed, iron is incorporated into proteins in the red blood cells and muscles that assist in oxygen transport and use.

• ***As Antibodies*** • Proteins also defend the body against disease. A virus—whether it is one that causes flu, smallpox, measles, or the common cold—enters the cells and multiplies there. One virus may produce 100 replicas of itself within an hour or so. Each replica can then burst out and invade 100 different cells, soon

Figure 6-9
One Cell and Its Associated Fluids



acids: compounds that release hydrogen ions in a solution.

bases: compounds that accept hydrogen ions in a solution.

buffers: compounds that help keep a solution's acidity or alkalinity constant.

acidosis (assi-DOE-sis): above-normal acidity in the blood and body fluids.

alkalosis (alka-LOE-sis): above-normal alkalinity (base) in the blood and body fluids.

The protein in the cells of the intestinal wall is **ferritin;** the carrier protein, **transferrin;** the storage protein, **ferritin** again; the red blood cell protein, **hemoglobin;** and the muscle cell protein, **myoglobin.**

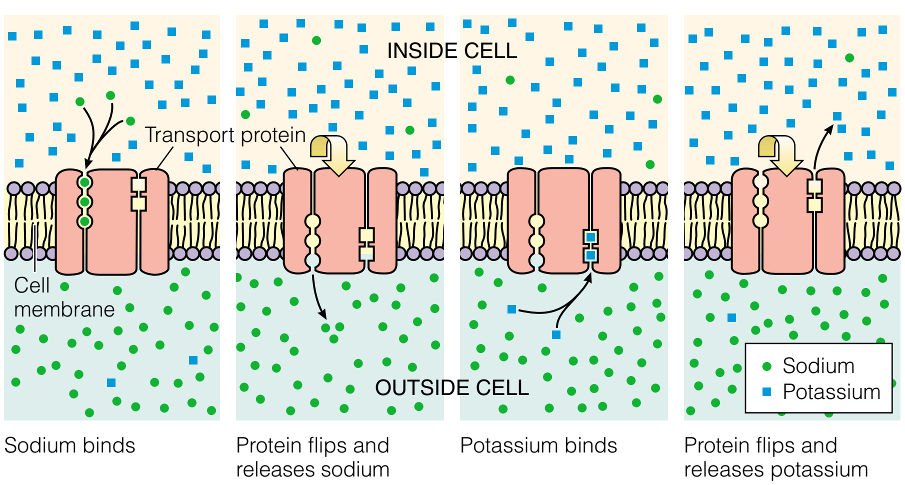


Figure 6-10
Transport Proteins

A transport protein within a cell membrane picks up substances on one side of the membrane and carries them to the other side without leaving the membrane. The substances being transported here are sodium and potassium. Maintaining a high concentration of potassium and a low concentration of sodium within the cells requires energy.

antibodies: large proteins of the blood and body fluids, produced by the immune system in response to the invasion of the body by foreign molecules (usually proteins called antigens); antibodies combine with and inactivate the foreign invaders, thus protecting the body.

antigen: a substance that elicits the formation of antibodies or an inflammation reaction from the immune system. A bacterium, a virus, a toxin, and a protein in food that causes allergy are all examples of antigens.

immunity: the body's ability to recognize and eliminate foreign invaders; see Chapter 18.

yielding 10,000 virus particles, which invade 10,000 cells. Left free to do their worst, they will soon overwhelm the body with disease.

Fortunately, when the body detects invaders, it manufactures antibodies, giant protein molecules designed specifically to combat them. The antibodies work so swiftly and efficiently that in a normal, healthy individual, most diseases never have a chance to get started. Without sufficient protein, though, the body cannot maintain its resistance to disease.

Each antibody is designed to destroy just one invader. Once the body has manufactured antibodies against a particular antigen (such as the measles virus), it remembers how to make them. Consequently, the next time the body encounters that same invader, it will produce antibodies even more quickly. In other words, the body develops a molecular memory, known as immunity.

• ***Other Roles*** • As mentioned earlier, proteins form integral parts of most body structures such as skin, muscles, and bones. They also participate in some of the body's most amazing activities such as blood clotting and vision. When a tissue is injured, a rapid chain of events leads to the production of fibrin, a stringy, insoluble mass of protein fibers that forms a clot from liquid blood. Later, more slowly, the protein collagen forms a scar to replace the clot and permanently heal the cut. The light-sensitive pigments in the cells of the retina are molecules of the protein opsin. Opsin responds to light by changing its shape, thus initiating the nerve impulses that convey the sense of sight to higher brain centers.

IN SUMMARY

The protein functions discussed here are summarized in the accompanying table. They are only a few of the many roles proteins play, but they convey some sense of the immense variety of proteins and their importance in the body.

Summary of Proteins' Functions

Growth and maintenance	Proteins form integral parts of most body structures such as skin, tendons, membranes, muscles, organs, and bones. As such, they support the growth and repair of body tissues.
Enzymes	Proteins facilitate chemical reactions.
Hormones	Proteins regulate body processes. (Some, but not all, hormones are made of protein.)
Antibodies	Proteins inactivate foreign invaders, thus protecting the body against diseases.
Fluid and electrolyte balance	Proteins help to maintain the volume and composition of body fluids.
Acid-base balance	Proteins help maintain the acid-base balance of body fluids by acting as buffers.
Transportation	Proteins transport substances, such as lipids, vitamins, minerals, and oxygen, around the body.
Energy	Proteins provide some fuel for the body's energy needs.

A Preview of Protein Metabolism

This section previews protein metabolism; Chapter 7 provides a full description. Cells have several metabolic options, depending on their amino acid needs.

protein turnover: the degradation and synthesis of endogenous protein.

endogenous (en-DODGE-eh-nus) **protein:** the protein in the body. In contrast, protein in foods is **exogenous** (eks-ODGE-eh-nus) **protein.**
- **endo** = within
- **gen** = arising
- **exo** = outside (the body)

• ***Protein Turnover*** • Within each cell, proteins are constantly being made and broken down. When proteins break down, they free amino acids to join the general circulation. Some of these amino acids may be promptly recycled into other proteins; others may be stripped of their nitrogen and used for energy. Together the constant degradation and synthesis of body proteins are known as protein turnover,[4] and the protein that participates in this flux is called endogenous protein.

• ***Nitrogen Balance*** • If the body maintains the same *amount* of protein in its tissues from day to day, it is in nitrogen balance. If the body adds protein, nitrogen status becomes positive; if it loses protein, nitrogen status becomes negative.

Normally, healthy adults receive enough protein to meet their needs, and they dispose of any excess. Their nitrogen intake equals their nitrogen output, and they are said to be in zero nitrogen balance, or nitrogen equilibrium. Nitrogen status is positive in growing infants and children, pregnant women, and people recovering from protein deficiency or illness; their nitrogen intake exceeds their nitrogen output. They are building protein tissues—adding new blood, bone, skin, and muscle cells to their bodies. In contrast, nitrogen status is negative in people who are starving or suffering other severe stresses such as burns, injuries, infections, and fever; their nitrogen output exceeds their nitrogen intake. During these times, the body loses protein as it breaks down body proteins for energy.

nitrogen balance: the amount of nitrogen consumed (N in) as compared with the amount of nitrogen excreted (N out) in a given period of time.*

Nitrogen equilibrium (zero nitrogen balance): N in = N out.
Positive nitrogen: N in > N out.
Negative nitrogen: N in < N out.

• ***Using Amino Acids to Make Proteins or Nonessential Amino Acids*** • Cells can assemble amino acids into the proteins they need to do their work. If a particular nonessential amino acid is not readily available, cells can dismantle another amino acid and combine the amino group with carbon fragments from glucose to make the needed one. If an essential amino acid is missing, the body may break down some of its own proteins to obtain it.

• ***Using Amino Acids to Make Other Compounds*** • Cells can also use amino acids to make other compounds. For example, the amino acid tyrosine is used to make the neurotransmitters norepinephrine and epinephrine, which relay nervous system messages throughout the body. Tyrosine can also be made into the pigment melanin, which is responsible for brown hair, eye, and skin color, or into the hormone thyroxin, which helps to regulate the metabolic rate. For another example, the amino acid tryptophan serves as a precursor for the neurotransmitter serotonin and the vitamin niacin.

neurotransmitters: chemicals that are released at the end of a nerve cell when a nerve impulse arrives there; they diffuse across the gap to the next cell and alter the membrane of that second cell to either inhibit or excite it.

• ***Using Amino Acids for Energy*** • Even though amino acids are needed to do the work that only they can perform—build vital proteins—they will be sacrificed to provide energy and glucose if need be. Without energy, cells die; without glucose, the brain and nervous system falter. When glucose or fatty acids are limited, cells are forced to use amino acids for energy and glucose. The body does not make a specialized storage form of protein as it does for carbohydrate and fat. Glucose is stored as glycogen in the liver and fat as triglycerides in adipose tissue, but protein in the body is available only as the working and structural components of the tissues. When the need arises, the body dismantles its tissue proteins and uses them for energy. Thus, over time, energy deprivation (starvation) always incurs wasting of lean body tissue as well as fat loss. An adequate intake of carbohydrates and fats spares amino acids from being used for energy and allows them to perform their unique roles.

Reminder: The making of glucose from noncarbohydrate sources such as amino acids is *gluconeogenesis*. The action of carbohydrate and fat in providing enough energy to allow amino acids to be used to build body proteins is known as the *protein-sparing action* of carbohydrate and fat.

• ***Deaminating Amino Acids*** • When amino acids are broken down (as occurs when they are used for energy), they are first deaminated—stripped of their nitrogen-containing amino groups. Deamination produces ammonia, which the cells release into the bloodstream. The liver picks up the ammonia, converts it into urea (a less toxic compound), and returns the urea to the blood. The kidneys filter urea out of the blood; thus the amino nitrogen ends up in the urine. Urea is produced from both exogenous and endogenous amino acids. The remaining carbon fragments may enter a number of metabolic pathways—for example, they may be used to make fat.

deamination (dee-AM-eh-NAY-shun): removal of the amino (NH_2) group from a compound such as an amino acid.

Urea metabolism is described in Chapter 7.

• ***Using Amino Acids to Make Fat*** • If a person eats more protein than the body needs, the amino acids are deaminated, the nitrogen is excreted, and the remaining

*The genetic materials DNA and RNA contain nitrogen, but the quantity is insignificant compared with the amount in protein. The average amino acid weighs about 6.25 times as much as the nitrogen it contains, so scientists can estimate the amount of protein in a sample of food, body tissue, or other material by multiplying the weight of the nitrogen in it by 6.25.

carbon fragments are converted to fat and stored for later use.* In this way, valuable, expensive, protein-rich foods can contribute to obesity.

IN SUMMARY

Proteins are constantly being synthesized and broken down as needed. The body's assimilation of amino acids into proteins and release of amino acids via protein degradation and excretion can be tracked by measuring nitrogen balance, which should be positive during growth and steady in adulthood. An energy deficit or an inadequate protein intake may force the body to use amino acids as fuel, creating a negative nitrogen balance. Protein eaten in excess of need is degraded and stored as body fat.

Protein in Foods

In the United States, where nutritious foods are abundant, people eat protein in such large quantities that even if its amino acid balance is not perfect, they receive all the amino acids they need. Where people eat only marginal amounts of protein-rich foods, however, the *quality* of the protein becomes crucial to their health. Hence, the protein quality of the diet is of great concern when making nutrition recommendations in countries where malnutrition is widespread.

Protein Quality

Food proteins that provide an unbalanced assortment of amino acids are poor-quality proteins. In countries where food is scarce, or where the people receive marginal or inadequate amounts of protein, the quality of the dietary protein determines, in large part, how well the children grow and how well the adults maintain their health.

Black beans and rice, a favorite Hispanic combination, together provide a full array of amino acids.

limiting amino acid: the essential amino acid found in the shortest supply relative to the amounts needed for protein synthesis in the body. Four amino acids are most likely to be limiting:
- Lysine.
- Methionine.
- Threonine.
- Tryptophan.

complete protein: a dietary protein containing all the essential amino acids in relatively the same amounts that human beings require; it may also contain nonessential amino acids.

• ***Limiting Amino Acids*** • To make proteins, a cell must have all the needed amino acids available simultaneously. The liver can produce any nonessential amino acid that may be in short supply so that the cells can continue linking amino acids into protein strands. If an essential amino acid is missing, though, a cell must dismantle its own proteins to obtain it. Therefore, to prevent protein breakdown, dietary protein must supply at least the nine essential amino acids plus enough nitrogen-containing amino groups and energy for the synthesis of the others. If the diet supplies too little of any essential amino acid, protein synthesis will be limited. The body makes whole proteins only; if one amino acid is missing, the others cannot form a "partial" protein. The body has no storage site for extra amino acids and is forced to either waste them or use them for another purpose. An essential amino acid supplied in less than the amount needed to support protein synthesis is called a *limiting* amino acid.

• ***Complete Protein*** • A complete dietary protein contains all the essential amino acids in relatively the same amounts as human beings require; it may or may not contain all the nonessential amino acids. Generally, proteins derived from animals (meat, fish, poultry, cheese, eggs, and milk) are complete, although gelatin is an exception (it lacks tryptophan and cannot support growth and health as a diet's sole protein). Proteins from plants (vegetables, grains, and legumes) have more

*Chemists sometimes classify amino acids according to the destinations of their carbon fragments after deamination. If the fragment leads to the production of glucose, the amino acid is called "glucogenic"; if it leads to the formation of ketone bodies, fats, and sterols, the amino acid is called "ketogenic." There is no sharp distinction between glucogenic and ketogenic amino acids, however. A few are both; most are considered glucogenic; only one (leucine) is clearly ketogenic.

diverse amino acid patterns, and some tend to be limiting in one or more essential amino acids. Some plant proteins (for example, corn protein) are notoriously incomplete. Others (for example, soy protein) are complete.

• ***Complementary Proteins*** • In general, plant proteins are of lower quality than animal proteins, and plants also offer less protein per unit (either weight or measure) of food. For this reason, many vegetarians combine plant-protein foods with different but complementary amino acid patterns to improve the quality of proteins in their diets. This strategy is called mutual supplementation, and it yields complementary proteins that contain all the essential amino acids in quantities sufficient to support health. The protein quality of the combination is greater than for either food alone (see Figure 6-11).

Many people have long believed that mutual supplementation at every meal is critical to protein nutrition. For most healthy vegetarians, though, it is not necessary to balance amino acids at each meal when protein intake is varied and energy intake is sufficient.[5] Vegetarians can receive all the amino acids they need over the course of a day, if they eat a variety of grains, legumes, seeds, nuts, and vegetables. Protein deficiency will develop, however, when fruits and certain vegetables make up the core of the diet, severely limiting the *quantity* and *quality* of protein. Highlight 6 shows how to plan a nutritious vegetarian diet.

• ***Digestibility*** • Ideally, a protein is both complete and easily digestible, so that enough amino acids are available for protein synthesis. Such a protein is a high-quality protein. Digestibility depends on a protein's configuration, other foods eaten with it, and reactions that influence the release of amino acids.

• ***Reference Protein*** • One of the most complete and digestible proteins is egg protein. Until the early 1990s, egg protein was used as the standard for measuring protein quality; it was assigned a value of 100, and the quality of other food proteins was determined based on how they compared with egg. Such a standard is called a reference protein. Now the Food and Agriculture Organization (FAO) of the United Nations and the World Health Organization (WHO) have established a new standard for the reference protein: the essential amino acid requirements of preschool-age children.

IN SUMMARY

A diet short in any of the essential amino acids limits protein synthesis. The best guarantee of amino acid adequacy is to eat foods containing complete proteins or mixtures of foods containing incomplete proteins so that each can supply the amino acids missing in the other. Vegetarians can meet their protein needs by eating a variety of whole grains, legumes, seeds, nuts, and vegetables.

Measures of Protein Quality

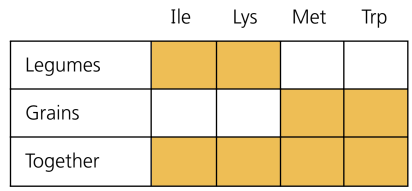
Researchers have developed several methods for evaluating the quality of food proteins. The object of all of these methods is to identify high-quality proteins—that is, proteins that are easily digestible and contain all of the essential amino acids in relatively the same proportion as human beings require. Proteins that are low in an essential amino acid cannot, by themselves, support protein synthesis. The following paragraphs briefly describe these measures; Appendix J provides more detail.

• ***Amino Acid Scoring*** • The simplest way to evaluate a food protein's quality is to determine its amino acid composition and compare it with a reference protein. Scientists can easily identify the limiting amino acid—it is the one that falls shortest compared with the reference. If the test protein's limiting amino acid is 70 percent of the amount found in the reference protein, it receives a score of 70. Such calculations fail to estimate digestibility, however.

Figure 6-11

An Example of Mutual Supplementation

In general, legumes provide plenty of isoleucine (Ile) and lysine (Lys), but fall short in methionine (Met) and tryptophan (Trp). Grains have the opposite strengths and weaknesses, making them a perfect match for legumes.



mutual supplementation: the strategy of combining two protein foods in a meal so that each food provides the essential amino acid(s) lacking in the other. Mutual supplementation is the dietary strategy that brings complementary proteins together in a meal.

complementary proteins: two or more proteins whose amino acid assortments complement each other in such a way that the essential amino acids missing from one are supplied by the other.

protein digestibility: a measure of the amount of amino acids absorbed from a given protein intake.

high-quality protein: an easily digestible, complete protein.

reference protein: a standard against which to measure the quality of other proteins.

Vegetarians obtain their protein from whole grains, legumes, nuts, vegetables, and, in some cases, eggs and milk products.

amino acid scoring: a method of evaluating protein quality by comparing a test protein's amino acid pattern with that of a reference protein; sometimes called **chemical scoring.**

biological value (BV): the amount of protein nitrogen that is retained for growth and maintenance, expressed as a percentage of the protein nitrogen that has been digested and absorbed; a measure of protein quality.

- ***Biological Value*** • The biological value (BV) of a protein measures its efficiency in supporting the body's needs. Scientists feed a given food protein to experimental animals as the sole protein in their diet and measure the animals' retention and loss of nitrogen. The more nitrogen retained, the higher the protein quality. (Recall that when an essential amino acid is missing, protein synthesis stops, and the remaining amino acids are deaminated and the nitrogen excreted.)

net protein utilization (NPU): the amount of protein nitrogen that is retained from a given amount of protein nitrogen eaten; a measure of protein quality.

- ***Net Protein Utilization*** • Like BV, net protein utilization (NPU) measures nitrogen retention. Instead of measuring retention of absorbed nitrogen (as in BV), NPU measures retention of food nitrogen.

protein efficiency ratio (PER): a measure of protein quality assessed by determining how well a given protein supports weight gain in growing rats; used to establish the protein quality for infant formulas and baby foods.

- ***Protein Efficiency Ratio*** • The protein efficiency ratio (PER) measures the weight gain of a growing animal and compares it to the animal's protein intake. Until recently, the PER was generally accepted in the United States and Canada as the official method for assessing protein quality.

protein digestibility–corrected amino acid score (PDCAAS): a measure of protein quality assessed by comparing the amino acid score of a food protein with the amino acid requirements of preschool-age children and then correcting for the true digestibility of the protein; recommended by the FAO/WHO and used to establish protein quality of foods for Daily Value percentages on food labels.

- ***PDCAAS*** • The protein digestibility–corrected amino acid score, or PDCAAS, method compares the amino acid contents of a protein with human amino acid requirements and corrects for digestibility. The protein's amino acid score is determined as described earlier, and then it is compared against the amino acid requirements of preschool-age children. This comparison reveals the most limiting amino acid. The rationale behind using the requirements of this age group is that if a protein will effectively support a young child's growth and development, then it will meet or exceed the requirements of older children and adults. Thus the PDCAAS method evaluates dietary protein quality for all age groups except infants. (The PER method described earlier is used to evaluate proteins for infants.)

To arrive at the PDCAAS, the amino acid score is multiplied by the food's protein digestibility percentage. Because the digestibility of many foods is similar in human beings and in rats, values for protein digestibility in rats are commonly used. Appendix J provides an example of how to calculate the PDCAAS and a table that lists the PDCAAS values of selected foods.

Protein Regulations for Food Labels

The Food and Drug Administration's (FDA) labeling regulations use the PDCAAS method to assess protein quality in foods intended for people over age one. For infant formulas and baby foods, the PER method using casein as a standard is used to measure protein quality.

All food labels must state the *quantity* of protein in grams. The "% Daily Value" for protein is not mandatory on all labels, but is required whenever a food makes a protein claim or is intended for consumption by children under four years old.* Whenever the Daily Value percentage is declared, researchers must calculate in the *quality* of the protein by using the PDCAAS method. Thus when a % Daily Value is stated for protein, it reflects both quantity and quality.

IN SUMMARY

The quality of protein is measured by its amino acid content, its digestibility, and its ability to support growth. Such measures are of great importance in dealing with malnutrition worldwide, but in the United States and Canada, where protein deficiency is not common, protein quality scores of individual foods deserve little emphasis.

*For labeling purposes, the Daily Values for protein are as follows: for infants, 14 grams; for children under age four, 16 grams; for older children and adults, 50 grams; for pregnant women, 60 grams; and for lactating women, 65 grams.

Health Effects and Recommended Intakes of Protein

As you know by now, protein is indispensable to life. It should come as no surprise that protein deficiency can have devastating effects on people's health. But like the other nutrients, protein in excess can also be harmful. This section examines the health effects and recommended intakes of protein.

Protein-Energy Malnutrition

When people are deprived of protein, energy, or both, the result is protein-energy malnutrition (PEM). Although PEM touches many adult lives, it most often strikes early in childhood. It is the most widespread form of malnutrition in the world, afflicting over 500 million children. Most of the 33,000 children who die each day are malnourished.[6]

Inadequate food intake leads to poor growth in children and to weight loss and wasting in adults. Children who are thin for their height may be suffering from acute PEM (recent severe food deprivation), whereas children who are short for their age have experienced chronic PEM (long-term food deprivation). Poor growth due to PEM is easy to overlook because a small child may look quite normal, but it is the most common sign of malnutrition.

PEM is most prevalent in Africa, Central America, South America, the Middle East, and East and Southeast Asia. In the United States, homeless people and those living in substandard housing in inner cities and rural areas have been diagnosed with PEM. In addition to those living in poverty, elderly people who live alone and adults who are addicted to drugs and alcohol are frequently victims of PEM. Adult PEM is also seen in people hospitalized with infections such as AIDS or tuberculosis; infections deplete body proteins, demand extra energy, induce nutrient losses, and alter metabolic pathways. PEM is also common in those suffering from the eating disorder anorexia nervosa. Prevention emphasizes frequent, nutrient-dense, energy-dense meals and, equally important, resolution of the underlying causes of PEM—poverty, infections, and illness.

• ***Classifying PEM*** • PEM occurs in two forms: marasmus and kwashiorkor, which differ in their clinical features (see Table 6-3). Appendix E describes the assessment and classification of PEM, and the following paragraphs present the three clinical syndromes—marasmus, kwashiorkor, and the combination of the two.

• ***Marasmus*** • Marasmus reflects a severe deprivation of food over a long time (chronic PEM) and therefore is caused by an inadequate energy *and* protein intake (and by inadequate essential fatty acids, vitamins, and minerals as well). Marasmus occurs most commonly in children from 6 to 18 months of age in all the overpopulated urban slums of the world. Children in impoverished nations simply do not have enough to eat and subsist on diluted cereal drinks that supply scant energy and protein of low quality; such food can barely sustain life, much less support growth. Consequently, marasmic children look like little old people—just skin and bones.

Without adequate nutrition, muscles, including the heart, waste and weaken. Because the brain normally grows to almost its full adult size within the first two years of life, marasmus impairs brain development and learning ability. Reduced synthesis of key hormones slows metabolism and lowers body temperature. There is little or no fat under the skin to insulate against cold. Hospital workers find that children with marasmus need to be wrapped up and kept warm. They also need love because they have often been deprived of parental attention as well as food.

Donated food saves some people from starvation, but it is usually insufficient to meet nutrient needs or even to provide a full belly for every person who is hungry.

protein-energy malnutrition (PEM), also called **protein-kcalorie malnutrition (PCM):** a deficiency of both protein and energy; the world's most widespread malnutrition problem, including kwashiorkor, marasmus, and instances in which they overlap.

acute PEM: protein-energy malnutrition caused by recent severe food restriction; characterized in children by thinness for height (wasting).

chronic PEM: protein-energy malnutrition caused by long-term food deprivation; characterized in children by short height for age (stunting).

WHO
www.who.org
Search for Protein energy malnutrition

marasmus (ma-RAZ-mus): a form of PEM that results from a severe deprivation, or impaired absorption, of energy, protein, vitamins, and minerals.

The extreme loss of muscle and fat characteristic of marasmus is apparent in this child's "matchstick" arms and legs.

Table 6-3
Features of Marasmus and Kwashiorkor in Children

Separating PEM into two classifications oversimplifies the condition, but at the extremes, marasmus and kwashiorkor exhibit marked differences. Marasmus-kwashiorkor mix presents symptoms common to both marasmus and kwashiorkor. In all cases, children are likely to develop diarrhea, infections, and multiple nutrient deficiencies.

Marasmus	Kwashiorkor
Infancy (less than 2 yr)	Older infants and young children (1 to 3 yr)
Severe deprivation, or impaired absorption, of protein, energy, vitamins, and minerals	Inadequate protein intake or, more commonly, infections
Develops slowly; chronic PEM	Rapid onset; acute PEM
Severe weight loss	Some weight loss
Severe muscle wasting, with fat	Some muscle wasting, with retention of some body fat
Growth: <60% weight-for-age	Growth: 60 to 80% weight-for-age
No detectable edema	Edema
No fatty liver	Enlarged fatty liver
Anxiety, apathy	Apathy, misery, irritability, sadness
Good appetite possible	Loss of appetite
Hair is sparse, thin, and dry; easily pulled out	Hair is dry and brittle; easily pulled out; changes color; becomes straight
Skin is dry, thin, and easily wrinkles	Skin develops lesions

The edema and enlarged liver characteristic of kwashiorkor is apparent in these children's swollen bellies. Malnourished children commonly have an enlarged abdomen from parasites as well.

kwashiorkor (kwash-ee-OR-core, kwash-ee-or-CORE): a form of PEM that results either from inadequate protein intake or, more commonly, from infections.

aflatoxin: a potent cancer-causing toxin produced by the mold *Aspergillus flavus* that infects grains and peanuts. The USDA tests grains and peanuts grown in the United States for aflatoxin contamination.

Reminder: *Edema* is the swelling of body tissue caused by excessive fluid in the interstitial spaces, seen in protein deficiency (among other conditions).

The starving child faces this threat to life by engaging in as little activity as possible—not even crying for food. The body musters all its forces to meet the crisis, so it cuts down on any expenditure of protein not needed for the functioning of the heart, lungs, and brain. Growth ceases; the child is no larger at age four than at age two. Digestive enzymes are in short supply, the GI tract lining deteriorates, and absorption fails. The child can't assimilate what little food is eaten.

• ***Kwashiorkor*** • Kwashiorkor typically reflects a sudden and recent deprivation of food (acute PEM). Kwashiorkor was originally a Ghanaian word meaning "the evil spirit that infects the first child when the second child is born." When a mother who has been nursing her first child bears a second child, she weans the first child and puts the second one on the breast. The first child, suddenly switched from nutrient-dense, protein-rich breast milk to a starchy, protein-poor cereal, soon begins to sicken and die. Kwashiorkor typically sets in between 18 months and two years.

Kwashiorkor usually develops rapidly as a result of protein deficiency or, more commonly, is precipitated by an illness such as measles or other infection.[7] Possibly, kwashiorkor is a form of food poisoning superimposed on malnutrition. One supporting piece of evidence is that kwashiorkor seems to appear only in rainy, tropical communities. Many temperate regions have experienced widespread famine, yet have not had kwashiorkor. Another clue is that under hot, humid conditions, a common mold, *Aspergillus flavus,* produces aflatoxin, a toxin that inhibits protein synthesis. When malnourished children are forced to eat moldy grain for lack of other food, their weakened bodies cannot defend against the toxin.

The loss of weight and body fat is usually not as severe in kwashiorkor as in marasmus, but there may be some muscle wasting. Proteins and hormones that previously maintained fluid balance diminish, and fluid leaks into the interstitial spaces. The child's limbs and face become swollen with edema, a distinguishing feature of kwashiorkor. Also contributing to the edema is the inflammatory response that accompanies kwashiorkor.[8] The lack of the protein carriers that transport fat out of the liver causes the belly to bulge with a fatty liver. The fatty liver lacks enzymes to clear poisons from the body, so their toxic effects are prolonged. Without sufficient tyrosine to make melanin, the child's hair loses its color; inadequate protein synthesis leaves the skin patchy and scaly, often with

sores that fail to heal. The lack of proteins to carry or store iron leaves iron free. Unbound iron is common in children with kwashiorkor and may contribute to their illnesses and deaths by promoting bacterial growth and free-radical damage.[9]

Free-radical damage is discussed fully in Highlight 11.

• ***Marasmus-Kwashiorkor Mix*** • The combination of marasmus and kwashiorkor is characterized by the edema of kwashiorkor with the wasting of marasmus. Most often, the child is suffering the effects of both malnutrition and infections. Some researchers believe that kwashiorkor and marasmus are two stages of the same disease. They point out that kwashiorkor and marasmus often exist side by side in the same community where children consume the same diet. They note that a child who has marasmus can later develop kwashiorkor. Some research indicates that marasmus represents the body's adaptation to starvation and that kwashiorkor develops when adaptation fails.

• ***Infections*** • In PEM, antibodies to fight off invading bacteria are degraded to provide amino acids for other uses, leaving the malnourished child vulnerable to infections. Blood proteins, including hemoglobin, are no longer synthesized, so the child becomes anemic and weak. Dysentery, an infection of the digestive tract, causes diarrhea, further depleting the body of nutrients. In the marasmic child, once infection sets in, kwashiorkor often follows.[10]

dysentery (DISS-en-terry): an infection of the digestive tract that causes diarrhea.

The combination of infections, fever, electrolyte imbalances, and anemia often leads to heart failure and occasionally sudden death. Infections combined with malnutrition are responsible for two-thirds of the deaths of young children in developing countries. Measles, which might make a healthy child sick for a week or two, kills a child with PEM within two or three days.

• ***Rehabilitation*** • If caught in time, the life of a starving child may be saved by careful nutrition therapy. Diarrhea will have depleted the body's potassium and disturbed other electrolyte balances. Careful correction of fluid and electrolyte imbalances usually raises the blood pressure and strengthens the heartbeat. After the first 24 to 48 hours, protein and food energy may be given in small quantities, with intakes gradually increased as tolerated.

Experts assure us that we possess the knowledge, technology, and resources to end hunger. Programs that have involved the local people in the process of identifying problems and devising solutions have met with some success. But until those who have the food, technology, and resources make fighting hunger a priority, the war on hunger will not be won (see Chapter 20 for more on hunger).

Given appropriate nutrition care, this child has successfully recovered from kwashiorkor.

Health Effects of Protein

While many of the world's people struggle to obtain enough food energy and protein, in developed countries both are so abundant that problems of excess are seen. Overconsumption of protein offers no benefits and may pose health risks.

The relationships between excess protein and chronic diseases are not clearly evident. Population studies have difficulty determining whether diseases correlate with animal proteins or with their accompanying saturated fats, for example. Studies that rely on data from vegetarians must sort out the many lifestyle factors, other than a "no-meat diet," that might explain relationships between protein and health.

• ***Heart Disease*** • As mentioned, foods rich in animal protein tend to be rich in saturated fats. Consequently, it is not surprising to find a correlation between animal-protein intake and heart disease, although no independent effect has been demonstrated. On the other hand, substituting soy protein for animal protein lowers blood cholesterol, especially in those with high blood cholesterol.[11]

Recent research suggests that the amino acid homocysteine may be an independent risk factor for heart disease.[12] When compared with others, men with elevated homocysteine were three times as likely to have heart attacks.[13] Researchers do not yet know the exact role homocysteine plays in heart disease, nor do they

understand what raises homocysteine in the blood, but they are following several leads in pursuit of the answers.[14] Interestingly, blacks seem to metabolize homocysteine more efficiently than whites, which may partially explain the lower incidence of heart disease among blacks despite their high blood pressure and smoking habits.[15] Coffee's role in heart disease has been controversial, but recent research suggests it is among the most influential factors in raising homocysteine, which may explain some of the adverse health effects of heavy consumption.[16] Homocysteine is also elevated with suboptimal intakes of B vitamins and can usually be corrected with vitamin B_{12}, vitamin B_6, and folate supplements.[17] Whether a high intake of these vitamins reduces the risk of heart attacks remains unclear, but preliminary research seems to suggest that it does.[18]

• ***Cancer*** • As in heart disease, the effects of protein and fats cannot be easily separated. Population studies suggest a correlation between high intakes of animal proteins and some types of cancer (notably, cancer of the colon, breast, kidneys, pancreas, and prostate).

Other risk factors for adult bone loss (osteoporosis) are sex, age, and race, as Highlight 12 explains.

• ***Adult Bone Loss (Osteoporosis)*** • Do high protein intakes accelerate bone loss? Calcium excretion rises as protein intake increases. Whether excess protein depletes the bones of their chief minerals is controversial and may depend upon the ratio of calcium to protein intakes.[19] An ideal ratio has not been established, but a young woman whose intake meets recommendations for both nutrients has a calcium-to-protein ratio of more than 20 to 1 (milligrams to grams). For most women in the United States, however, average calcium intakes are lower and protein intakes are higher, yielding a 9-to-1 ratio, which may produce calcium losses that compromise bone health.[20] In contrast, moderate increases in physical activity and calcium intake may protect against such losses. In establishing calcium recommendations, the Committee on Dietary Reference Intakes considered protein's effect on calcium retention, but did not find sufficient evidence to warrant an adjustment.[21]

• ***Weight Control*** • Protein-rich foods are often fat-rich foods that contribute to obesity with its accompanying health risks. As Highlight 8 explains, weight-loss gimmicks that encourage a high-protein diet are rarely effective; overweight people have better success with diets that provide adequate protein, minimal fat, and ample energy from carbohydrates. The higher a person's intake of protein-rich foods such as meat and milk, the more likely that fruits, vegetables, and grains will be crowded out, making the diet inadequate in other nutrients.

IN SUMMARY

Protein deficiencies arise from both energy-poor and protein-poor diets and lead to the devastating diseases of marasmus and kwashiorkor. Together, these diseases are known as PEM (protein-energy malnutrition), the major form of malnutrition causing death in children worldwide. Excesses of food energy and protein offer no advantage; in fact, overconsumption of protein-rich foods may incur health risks as well.

Recommended Intakes of Protein

As mentioned earlier, the body continuously breaks down and loses its proteins and cannot store amino acids. To replace protein, the body needs dietary protein for two reasons: first, food protein is the only source of the *essential* amino acids; and second, it is the only practical source of *nitrogen* with which to build the nonessential amino acids and other nitrogen-containing compounds.

The *Diet and Health* report recommends that people's fat intakes should contribute 30 percent or less of total food energy, and carbohydrate, 55 percent or more—which leaves about 15 percent for protein. Current intakes in the United States and Canada, though higher than recommendations, do not seem to be high

enough to cause harm. The *Diet and Health* report advises people to maintain moderate protein intakes—between the RDA and twice the RDA.

• ***Protein RDA*** • The protein RDA for healthy adults is 0.8 grams per kilogram of appropriate body weight per day. For infants and children, the RDA is higher. When compared to total energy intake, however, the protein RDA for infants and children is similar to that for adults as Table 6-4 shows. The RDA generously covers the needs for replacing worn-out tissue, so it increases for larger people; it also covers the needs for building new tissue during growth, so it increases for infants, children, and pregnant women. The accompanying "How to" shows how to calculate your RDA for protein.

In setting the RDA, the committee assumes that people are healthy and do not have unusual metabolic needs for protein; that the protein eaten will be of mixed quality; and that the body will use the protein about as efficiently as it uses reference proteins. In addition, the committee assumes that the protein is consumed along with sufficient carbohydrate and fat to provide adequate energy and that other nutrients in the diet are adequate.

• ***Adequate Energy*** • Note the qualification "adequate energy" in the preceding statement, and consider what happens if energy intake falls short of needs. An intake of 50 grams of protein, which is equal to 200 kcalories, provides about 10 percent of the total energy from protein, if the person receives 2000 kcalories a day. But if the person cuts energy intake drastically—to, say, 800 kcalories a day—then an intake of 200 kcalories from protein is suddenly 25 percent of the total; yet it's still the same number of grams. The protein intake is reasonable, but the energy intake is not; the low energy intake will force the body to use the protein to meet energy needs rather than to replace lost body protein. Similarly, if the person's energy intake is high—say, 4000 kcalories—the 50-gram protein intake will represent only 5 percent of the total; yet it *still* is a reasonable protein intake. Again, the energy intake is unreasonable for most people, but in this case, it will permit the protein to be used to meet the body's needs.

Be careful when judging protein intake as a percentage of energy. Always ascertain the number of grams as well, and compare it with the RDA or another standard stated in grams. A recommendation stated as a percentage of energy intake is useful only if the energy intake is within reason.

• ***Protein in Abundance*** • Many people tend to overvalue protein, perhaps because they have been so impressed with its many critical roles in the body. They think they need *lots* of protein, when, in fact, they are already receiving plenty. A high protein intake increases the work of the kidneys.[22] Excretion of the end products of protein metabolism depends, in part, on an adequate fluid intake and healthy kidneys.

Table 6-4

Protein RDA as a Percentage of Energy RDA

When expressed as a percentage of energy intake, the protein requirement represents about 10 percent of the energy RDA.

Age (yr)	Protein RDA (g/kg)	Protein RDA (in kCalories) as a Percentage of Energy RDA (%)
0 to ½	2.2	8.0
½ to 1	1.6	6.5
1 to 3	1.2	4.9
4 to 6	1.1	5.3
7 to 10	1.0	5.6
Males		
11 to 14	1.0	7.2
15 to 18	0.9	7.9
19 to 24	0.8	8.0
25 to 50	0.8	8.7
51 +	0.8	11.0
Females		
11 to 14	1.0	8.4
15 to 18	0.8	8.0
19 to 24	0.8	8.4
25 to 50	0.8	9.1
51 +	0.8	10.5

HOW TO Calculate Recommended Protein Intakes

To figure your protein RDA:

- Look up the appropriate weight for a person of your height (inside back cover). If your present weight falls within that range, use it for the following calculations. If your present weight falls outside the range, use the midpoint of the acceptable weight range as your reference weight.
- Convert pounds to kilograms, if necessary (pounds divided by 2.2 equals kilograms).
- Multiply kilograms by 0.8 to get your RDA in grams per day. (Males 18 years old and younger, multiply by 0.9.)

Example:

Weight = 150 lb.

150 lb ÷ 2.2 lb/kg = 68 kg (rounded off).

68 kg × 0.8 g/kg = 54 g protein (rounded off).

Chapter 14 discusses athletes' protein needs further.

Most people in developed countries such as the United States and Canada receive much more protein than they need. Even athletes typically don't need to increase their protein intakes. This is not surprising considering the abundance of food eaten and the central role meats hold in the North American diet. A single ounce of meat delivers about 7 grams of protein, so one 8-ounce serving of meat alone supplies more than the RDA for an average-sized person. Besides meat, well-fed people eat many other nutritious foods, many of which also contain protein.

To illustrate how easy it is to overconsume protein, consider the *minimum* recommended servings for the Daily Food Guide. Six servings from the bread, cereal, rice, and pasta group provide about 18 grams of protein; 3 servings of vegetables deliver about 6 grams; 2 servings of milk offer 16 grams; and 2 servings (about 5 ounces) of meat contain about 35 grams. This totals 75 grams of protein—higher than recommendations for most people and slightly lower than the average intake of people in the United States. (The accompanying "How to" feature describes how to estimate protein in foods.)

Just think how much more protein people receive when they eat additional servings. No wonder most people in the United States and Canada get more protein than they need. If they have an adequate *food* intake, they have a more-than-adequate protein intake. The key diet-planning principle to emphasize for protein is moderation. Even though most people receive plenty of protein, some feel compelled to take supplements as well, as the next section describes.

IN SUMMARY

Optimally, the diet will be adequate in energy from carbohydrate and fat and will deliver 0.8 grams of protein per kilogram of normal body weight each day. U.S. and Canadian diets are typically more than adequate in this respect, and protein or amino acid supplements are superfluous.

Protein and Amino Acid Supplements

Health food stores and popular magazine articles advertise a wide variety of protein supplements, and people take these supplements for many different reasons, all of them unfounded. Athletes take them to build muscle. Dieters take them to spare their bodies' protein while losing weight. Women take them to strengthen their fingernails. People take individual amino acids, too—to cure herpes, to make themselves sleep better, to lose weight, and to relieve pain and depression.* Like many other magic solutions to health problems, protein and amino acid supplements don't work these miracles, and they can be harmful.

Muscle work builds muscle; protein supplements do not, and athletes do not need them. Instead, athletes need a well-balanced diet that provides sufficient dietary protein and adequate food energy. Food energy spares body protein; carbohydrate and fat serve this purpose equally well, and carbohydrate is safer. Fingernails are not affected by protein supplements, provided the diet is adequate.

Use of amino acids as dietary supplements is *inappropriate,* especially for:

- All women of childbearing age.
- Pregnant or lactating women.
- Infants, children, and adolescents.
- Elderly people.
- People with inborn errors of metabolism that affect their bodies' handling of amino acids.
- Smokers.
- People on low-protein diets.
- People with chronic or acute mental or physical illnesses who take amino acids without medical supervision.

Furthermore, protein supplements are expensive, less completely digested than protein-rich foods, and, when used as replacements for such foods, often downright dangerous. The "liquid protein" diet, advocated some years ago for weight loss, caused deaths in many users; even some physician-supervised protein-sparing fasts based on liquid protein have caused abnormal heart rhythms. The FDA warns that their use as a total diet without medical supervision "may cause serious illness or death."

Single amino acids do not occur naturally in foods and offer no benefit to the body; in fact, they can be harmful. The body was not designed to handle the high concentrations and unusual combinations of amino acids found in supplements. An excess of one amino acid can create such a demand for a carrier that it prevents

*Canada allows single amino acid supplements to be sold only as drugs or as food additives.

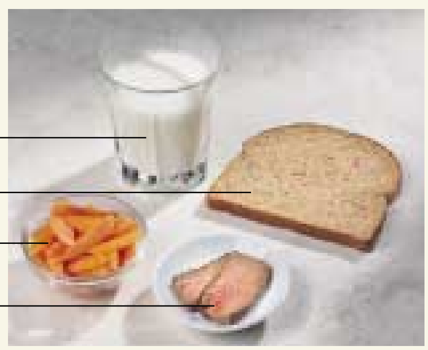
HOW TO Use the Exchange System to Estimate Protein

Exchange	Protein (g)
Milks	8
Meats	7
Starch	3
Vegetables	2
Fruits	—
Fats	—

The exchange system provides an easy way to estimate dietary protein. The foods on the milk and meat lists supply protein in abundance: a cup of milk provides 8 grams of protein; an ounce of meat, 7 grams. The starch and vegetable lists contribute small amounts of protein, but they can add up to significant quantities; fruits and fats provide no protein.

To estimate the protein in this meal, you first need to recognize that this burrito contains about ½ cup pinto beans and ½ ounce shredded cheese wrapped in a tortilla, 1 cup of milk and an apple. Then you need to translate these portions into exchanges: 1½ meats, 1 starch, 1 milk, and 1 fruit, respectively.

Lunch		Exchange	Protein (g) Estimate	Protein (g) Actual
½ c pinto beans	=	1 meat	7	
½ oz cheese	=	½ meat	4	14
1 tortilla	=	1 starch	3	
1 c milk	=	1 milk	8	8
1 apple	=	1 fruit	—	—
			22	22



Milks and meats provide lots of protein; starch and vegetables contain a little; fruits and fats have none.

Using the exchange system to estimate, this lunch provides about 22 grams of protein. A computer diet analysis program calculated the same. The exchange system sometimes over- or underestimates the protein contents of individual foods, but for most, its estimates of daily intakes are close. In any case, for nutrients eaten in such large quantities as protein, a difference of a few grams in a day's total is insignificant.

the absorption of another amino acid, leading to a deficiency. Those amino acids winning the competition enter in excess, creating the possibility of a toxicity. Toxicity of single amino acids in animal studies raises concerns about their use in human beings. Anyone considering taking amino acid supplements should check with a physician first.

In two cases, recommendations for single amino acid supplements have led to widespread public use—lysine to prevent or relieve the infections that cause herpes cold sores on the mouth or genital organs, and tryptophan to relieve pain, depression, and insomnia. In both cases, enthusiastic popular reports preceded

careful scientific experiments. A review of the research indicates that lysine may suppress herpes infections in some individuals and appears safe (up to 3 grams per day) when taken in divided doses with meals.[23]

Tryptophan is also effective with respect to pain and sleep, but its use for these purposes is still experimental. More than 1500 people who elected to take tryptophan supplements developed a rare blood disorder known as eosinophilia-myalgia syndrome (EMS). EMS is characterized by severe muscle pain, extremely high fever, and, in over three dozen cases, death. Treatment usually involves physical therapy and low doses of corticosteroids to relieve symptoms temporarily. Early evidence suggested that a major tryptophan processing plant may have introduced contaminants that caused the disease, but later research indicated that multiple factors were involved; the exact causes of EMS remain unknown. The FDA issued a recall of all products containing tryptophan.

IN SUMMARY

Normal, healthy people never need protein or amino acid supplements. It is safest to obtain lysine, tryptophan, and all other amino acids in protein-rich foods, eaten with carbohydrate to facilitate their use in the body. With all that we know about science, it is hard to improve on nature.

M t Click

These problems will give you practice in doing simple nutrition-related calculations using hypothetical situations (see Appendix K for answers). Once you have mastered these examples, you will be prepared to examine your own protein needs. Be sure to show your calculations for each problem.

1. Compute recommended protein intakes for people of different sizes. Refer to the "How to" on p. 181 and compute the protein recommendation for the following people. The intake for a woman 5 feet 8 inches tall is computed for you as an example.

   A woman 5 feet 8 inches tall is 68 inches tall. From the table on the inside back cover, the midpoint in the green area for this woman is 144 pounds.

   $$144 \text{ lb} \div 2.2 \text{ lb/kg} = 65 \text{ kg}.$$
   $$0.8 \text{ g/kg} \times 65 \text{ kg} = 52 \text{ g protein per day}.$$

   a. A woman 5 feet 1 inch tall.
   b. A man (18 years) 6 feet 4 inches tall.

2. The chapter warns that recommendations based on percentage of energy intake are not always appropriate. Consider a man 26 years old who is 5 feet 10 inches tall, weighs 163 pounds, is moderately active, and eats 3500 kcalories/day with 10 percent of the kcalories from protein.
   a. What is this man's protein intake? Show your calculations.
   b. Is his protein intake appropriate? Too high? Too low? Justify your answer.

This exercise should help you develop a perspective on protein recommendations.

S

These questions will help you review the chapter. You will find the answers in the discussions on the pages provided.

1. How does the chemical structure of proteins differ from the structures of carbohydrates and fats? (pp. 161–163)
2. Describe the structure of amino acids, and explain how their sequence in proteins affects the proteins' shapes. What are essential amino acids? (pp. 161, 163)
3. Describe protein digestion and absorption. (pp. 164–166)
4. Describe protein synthesis. (pp. 166–168)
5. Describe some of the roles proteins play in the human body. (pp. 168–172)
6. What are enzymes? What roles do they play in chemical reactions? Describe the differences between enzymes and hormones. (pp. 169–170)
7. How does the body use amino acids? What is deamina-

tion? Define nitrogen balance. What conditions are associated with zero, positive, and negative balance? (p. 173)
8. What factors affect the quality of dietary protein? What is a complete protein? (pp. 174–175)
9. How can vegetarians meet their protein needs without eating meat? (p. 175)
10. What are the health consequences of ingesting inadequate protein and energy? Describe marasmus and kwashiorkor. How can the two conditions be distinguished, and in what ways do they overlap? (pp. 177–179)
11. How might protein excess, or the type of protein eaten, influence health? (pp. 179–180)
12. What factors are considered in establishing recommended protein intakes? (p. 181)
13. Which food lists of the exchange system supply protein in abundance? In moderation? Not at all? (p. 183)
14. What are the benefits and risks of taking protein and amino acid supplements? (pp. 182–184)

These questions will help you prepare for an exam. Answers can be found in Appendix K.

1. Which part of its chemical structure differentiates one amino acid from another?
   a. its side group
   b. its acid group
   c. its amino group
   d. its double bonds
2. Isoleucine, leucine, and lysine are:
   a. proteases.
   b. polypeptides.
   c. essential amino acids.
   d. complementary proteins.
3. In the stomach, hydrochloric acid:
   a. denatures proteins and activates pepsin.
   b. hydrolyzes proteins and denatures pepsin.
   c. emulsifies proteins and releases peptidase.
   d. condenses proteins and facilitates digestion.
4. Proteins that facilitate chemical reactions are:
   a. buffers.
   b. enzymes.
   c. hormones.
   d. antigens.
5. If an essential amino acid that is needed to make a protein is unavailable, the cells must:
   a. deaminate another amino acid.
   b. substitute a similar amino acid.
   c. break down proteins to obtain it.
   d. synthesize the amino acid from glucose and nitrogen.
6. Eating two foods together so that each provides an amino acid that the other lacks is known as:
   a. dual deamination.
   b. random limitation.
   c. mutual supplementation.
   d. double complementation.
7. The protein efficiency ratio and PDCAAS are two methods used to:
   a. determine protein quality.
   b. assess protein-energy malnutrition.
   c. estimate the weight of nitrogen in a food.
   d. calculate the percentage kcalories from protein.
8. Marasmus develops from:
   a. too much fat clogging the liver.
   b. megadoses of amino acid supplements.
   c. inadequate protein and energy intake.
   d. excessive fluid intake causing edema.
9. The protein RDA for a healthy adult who weighs 180 pounds is:
   a. 50 milligrams/day.
   b. 65 grams/day.
   c. 180 grams/day.
   d. 2000 milligrams/day.
10. Which of these foods contains the least protein per serving?
   a. rice
   b. broccoli
   c. pinto beans
   d. orange juice

N

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Vegetarian, Mediterranean, and Other Meat-Restricted Foodways

The waiter presents this evening's specials: a fresh spinach salad topped with mandarin oranges, raisins, and sunflower seeds, served with a bowl of pasta smothered in a mushroom and tomato sauce and topped with grated parmesan cheese. Then this one: a salad made of chopped parsley, scallions, celery, and tomatoes mixed with bulgur wheat and dressed with olive oil and lemon juice, served with a spinach and feta cheese pie. Do these meals sound good to you? Or is something missing . . . a pork chop or ribeye, perhaps?

Would vegetarian fare be acceptable to you some of the time? Most of the time? Ever? Perhaps it is helpful to recognize that dietary choices fall along a continuum—from one end, where people eat no meat or foods of animal origin, to the other end, where they eat generous quantities daily. Meat's place in the diet has been the subject of much research and controversy, as this highlight will reveal. One of the missions of this highlight, in fact, is to identify the *range* of meat intakes most compatible with health.

People who choose to exclude meat and other animal-derived foods from their diets today do so for many of the same reasons the Greek philosopher Pythagoras cited in the sixth century B.C.: physical health, ecological responsibility, and philosophical concerns. They might also cite world hunger issues, economic reasons, ethical concerns, or religious beliefs as motivating factors.

Vegetarians generally are categorized, not by their motivations, but by the foods they choose not to eat (see the glossary on p. 188). Some exclude red meat only; some also exclude chicken or fish; others also exclude eggs; and still others exclude milk and milk products as well. As you will see, though, the foods a person *excludes* are not nearly as important as the foods a person *includes* in the diet. Most vegetarian diets include a variety of grains, vegetables, legumes, and fruits, which offer abundant complex carbohydrates and fibers, an assortment of vitamins and minerals, and little fat—characteristics that reflect current dietary recommendations aimed at reducing obesity and the risks of several chronic diseases such as hypertension, heart disease, and cancer. Vegetarian diets that are well planned can offer sound nutrition and health benefits to adults.[1]

This highlight first looks at the health benefits and potential problems of vegetarian diets and then shows how to plan a well-balanced vegetarian diet. It closes with a description of the Mediterranean diet—an ethnic pattern of eating that includes very little meat and exceeds current dietary recommendations for fat and alcohol, yet still seems to support good health.

A balanced meal need not include meat to be nutritious.

Health Benefits of Vegetarian Diets

Research on the health impacts of vegetarianism would be relatively easy if vegetarians differed from other people only in not eating meat. Many vegetarians, however, have adopted lifestyles that differentiate them from others: they typically maintain a healthy weight, use no tobacco or illicit drugs, use little (if any) alcohol, and are physically active.[2] Researchers must account for these lifestyle differences before they can determine which aspects of health correlate just with diet. Even then, *correlations* merely reveal what health factors *go with* the vegetarian diet, not what health effects may be *caused by* the diet. Without more evidence, conclusions remain tentative. Still, with all these qualifications, research findings seem to suggest that vegetarian diets offer some health benefits.

Weight Control

In general, vegetarians maintain a healthier body weight than nonvegetarians. Since obesity impairs health in a number of ways, this gives vegetarians a health advantage.

Blood Pressure

Appropriate body weight helps to maintain a healthy blood pressure, as does a diet low in total fat and saturated fat and high in fiber, fruits, and vegetables.[3] Lifestyle factors also seem to influence blood pressure: smoking and alcohol intake raise blood pressure, and physical activity lowers it.

Coronary Artery Disease

Fewer vegetarians than meat eaters suffer from diseases of the heart and arteries. The dietary factor most directly related to coronary artery disease is saturated fat, and in general, vegetarian diets are lower in total fat, saturated fat, and cholesterol than typical meat-based diets. Vegetarian diets are also higher in dietary fiber, another factor that helps control blood lipids.

When vegetarians are fed meat, which contains saturated fat, their blood lipid profiles change for the worse; when meat eaters are fed a low-fat vegetarian diet, their blood lipid profiles and blood pressure improve.[4]

Glossary

lactovegetarians: people who include milk and milk products, but exclude meat, poultry, fish, seafood, and eggs from their diets.
- **lacto** = milk

lacto-ovo-vegetarians: people who include milk, milk products, and eggs, but exclude meat, poultry, fish, and seafood from their diets.
- **ovo** = egg

macrobiotic diets: extremely restrictive diets limited to a few grains and vegetables; based on metaphysical beliefs and not on nutrition.

meat replacements: products formulated to look and taste like meat, fish, or poultry; usually made of textured vegetable protein.

omnivores: people who have no formal restriction on the eating of any foods.
- **omni** = all
- **vores** = to eat

semivegetarians: people who include some, but not all, groups of animal-derived foods in their diets; they usually exclude red meat, but may occasionally include poultry, fish, and seafood; sometimes called **partial vegetarians.**

tempeh (TEM-pay): a fermented soybean food, rich in protein and fiber.

textured vegetable protein: processed soybean protein used in vegetarian products such as soy burgers; see *meat replacements.*

tofu (TOE-foo): a curd made from soybeans, rich in protein and often fortified with calcium; used in many Asian and vegetarian dishes in place of meat.

vegans (VAY-guns or VEJ-ans): people who exclude all animal-derived foods (including meat, poultry, fish, eggs, and dairy products) from their diets; also called **pure vegetarians, strict vegetarians,** or **total vegetarians.**

vegetarians: a general term used to describe people who exclude meat, poultry, fish, or other animal-derived foods from their diets.

Similarly, semivegetarians who eat one to three servings of meat per week have blood lipids between the low blood lipids of vegetarians and the higher lipids of nonvegetarians.[5]

Cancer

Seventh-Day Adventists, a religious group whose foodways center on a lacto-ovo-vegetarian diet, have a significantly lower mortality rate from cancer than the rest of the population, even after all the cancers attributed to smoking and alcohol are discounted.[6] Their low cancer rates may be due to their vegetarian diets; evidence is overwhelming that high intakes of fruits and vegetables reduce the risks of cancer.[7]

Some scientific findings indicate that vegetarian diets are associated not only with lower cancer mortality in general, but with lower incidence of cancer at specific sites as well, most notably, colon cancer.[8] People with colon cancer seem to eat more meat, more saturated fat, and less fiber than others without cancer. High-protein, high-fat, low-fiber diets create an environment in the colon that promotes the development of cancer in some people. A high-meat diet has been associated with other cancers as well.[9]

In general, then, adults who eat vegetarian diets can reduce their risks of several chronic diseases, including obesity, high blood pressure, heart disease, and cancer. But there is nothing mysterious about the vegetarian diet; it simply includes ample fruits, vegetables, whole grains, and legumes—foods that are higher in fiber, richer in antioxidant vitamins, and lower in fats than meat-based diets.[10] Some people find it easier to meet today's dietary recommendations for health by following a vegetarian diet than by eating meals with meat. A meat eater can gain some of the same advantages by limiting meat intake to the recommended 5 to 7 ounces daily and selecting lean cuts, as well as including abundant grains, fruits, and vegetables.

Conversely, both vegetarian and meat-based diets can be detrimental to health when overloaded with fat. A vegetarian who dines on cheddar cheese, butter sauces, sour cream, and deep-fried vegetables invites the same health hazards as the person who overeats high-fat meats. And both diets, if not properly balanced, can lack nutrients. Poorly planned vegetarian diets typically lack iron, zinc, calcium, vitamin B_{12}, and vitamin D; without planning, the meat eater's diet may lack vitamin A, vitamin C, folate, and fiber, among others.

Vegetarian Resource Group
www.vrg.org

Problems Associated with Vegetarian Diets

The negative health aspects of any diet, including vegetarian diets, reflect poor diet planning. Careful attention to energy intake and specific problem nutrients can ensure adequacy. Diet planning during pregnancy, lactation, infancy, childhood, and illness, in particular, must provide for the increases in energy and nutrients needed during those times—when the consequences of poor nutrition can be great.

Adequacy of Most Vegetarian Diets

Vegetarians who include milk products and eggs can meet recommendations for most nutrients about as easily as nonvegetarians.[11] Such diets provide enough energy, protein, and other nutrients to support the health of adults and the growth of children and adolescents.

Inadequacy of Strict Vegetarian Diets

Achieving adequate energy and nutrient intakes may be difficult for the vegan who excludes all animal products, and particularly for growing children and pregnant and lactating women. Foods of plant origin generally offer much less energy per bite than foods of animal origin. While a diet

that delivers a lot of food with relatively little energy may be advantageous for many adults, it can be detrimental for children who need energy-dense foods for growth. Vegan diets can fail to provide sufficient energy to support the growth of a child within a quantity of food small enough for the child to eat. A child's small stomach can hold only so much food, and a vegan child may feel full before eating enough to meet nutrient and energy needs. A vegan child's diet should emphasize cereals, legumes, and nuts to meet protein and energy needs in a small volume. Meat, which contains abundant protein, iron, and food energy in less bulk, supports the growth of children more efficiently. Compared with meat-eating children, vegan children tend to be smaller in height and lighter in weight; their low energy intakes can impair growth.[12]

When vegan children get their protein only from plant foods, they may need protein intakes higher than the RDA for normal growth and health. The standard protein recommendations may be inadequate to support the growth of vegan children, but specific recommendations have not been established.

Approximately 2 out of every 15 households include one or more vegetarians. These people number some 12 million nationwide, representing an eightfold increase over the past two decades.[13] Those who plan their diets carefully easily obtain all the nutrients they need to support good health.

Vegetarian Diet Planning

The vegetarian has the same meal-planning task as any other person—using a variety of foods that will deliver all the needed nutrients within an energy allowance that maintains a healthy body weight. An added challenge is to do so with fewer foods.

Well-planned vegetarian meals can provide adequate amounts of all the nutrients a person needs for good health. Vegetarians can follow the Daily Food Guide presented in Chapter 2 with a few modifications (see Table H6-1). Those who include milk products and eggs can follow the regular plan, using legumes and products made from them, such as peanut butter, tempeh, and tofu, in place of meat. Those who do not use milk can use soy milk fortified with calcium, vitamin D, and vitamin B_{12}. Vegetarian adults should include at least one cup of dark green vegetables daily to help meet iron needs and legumes to help meet zinc needs. In general, these tactics ensure adequate intakes of the main nutrients vegetarian diets might otherwise lack: iron, zinc, calcium, vitamin B_{12}, and vitamin D. In contrast, most vegetarians easily obtain large quantities of the nutrients that are abundant in plant foods: thiamin, riboflavin, folate, and vitamins B_6, C, A, and E.

FDA
www.fda.gov
Visit foods
Search for Vegetarian

Protein

Protein is not the problem it was once thought to be for vegetarian diets. People who use animal-derived foods such as milk and eggs receive high-quality proteins and are unlikely to develop protein deficiencies. Even those who eat only plant-derived foods are unlikely to develop protein deficiencies provided that energy intakes are adequate and the protein sources varied.[14] The proteins of whole grains, legumes, seeds, nuts, and vegetables can provide adequate amounts of all the amino acids. An advantage of many vegetarian protein foods is that they are generally lower in saturated fat than meats and are often higher in fiber and richer in some vitamins and minerals.

To ease meal preparation, vegetarians sometimes use meat replacements made of textured vegetable protein (soy protein). These foods are formulated to look and taste like meat, fish, or poultry. Many of these products are designed to match the known nutrient contents of animal-protein foods, but sometimes they fall short. A wise vegetarian does

Table H6–1
Daily Food Guide for Vegetarian Meal Planning

Food Group	Suggested Daily Servings	Serving Sizes
Breads, cereals, rice, pasta, and other grain products	6 to 11	1 slice bread ½ bun, bagel, or English muffin ½ c cooked cereal, rice, or pasta 1 oz ready-to-eat cereal
Vegetables	3 to 5[a]	½ c cooked or chopped raw vegetables 1 c raw leafy vegetables
Fruits	2 to 4	1 medium-sized piece fresh fruit ¾ c fruit juice ½ c canned, cooked, or chopped raw fruit ¼ c dried fruit
Legumes, nuts, seeds, eggs, and other meat substitutes	2 to 3	½ c cooked legumes ¼ c tofu or tempeh 1 c soy milk 2 tbs peanut butter, nuts, or seeds (these tend to be high in fat, so use sparingly) 1 egg or 2 egg whites
Milk, yogurt, cheese, and other milk products	2 to 3[b]	1 c milk 1 c yogurt 1½ oz cheese

[a]Include 1 cup of dark green vegetables daily to help meet iron requirements.
[b]People who do not use milk or milk products: use soy milk fortified with calcium, vitamin D, and vitamin B_{12}. Other nonmilk calcium-rich food sources are provided in Chapter 12.
Source: Adapted from Position of The American Dietetic Association: Vegetarian diets, *Journal of the American Dietetic Association* 97 (1997): 1320.

not rely on these products too heavily, but learns to use a variety of whole foods instead. Vegetarians may also use soybeans in the form of bean curds, or tofu, to bolster protein intake.

Iron

Getting enough iron can be a problem even for meat eaters, and those who eat no meat must pay special attention to their iron intake. The iron in plant foods such as legumes, dark green leafy vegetables, iron-fortified cereals, and whole-grain breads and cereals is not readily absorbed. Iron absorption is enhanced by vitamin C, though, and vegetarians typically eat many vitamin C–rich fruits and vegetables, so they suffer no more iron-deficiency anemia than other people do.[15]

Zinc

Zinc is similar to iron in that meat is its richest food source and zinc from plant sources is not well absorbed. In addition, soy, which is commonly used as a meat alternate, interferes with zinc absorption. Nevertheless, most vegetarian adults are not zinc deficient.[16] Perhaps the best advice to vegetarians regarding zinc is to eat a variety of nutrient-dense foods; include grains, nuts, and legumes such as black-eyed peas, pinto beans, and kidney beans; and maintain an adequate energy intake. For vegetarians who include seafood, oysters, crabmeat, and shrimp are rich in zinc.

Calcium

The calcium intakes of lactovegetarians are similar to those of the general population, but people who use no milk risk deficiency. Careful planners select calcium-rich foods, such as calcium-fortified juices or soy milk, in ample quantities regularly. This is especially important for children. Soy formulas for infants are fortified with calcium and can be used in cooking, even for adults. Other good calcium sources include calcium-set tofu, some legumes, some green vegetables such as broccoli and turnip greens, some nuts such as almonds, and certain seeds such as sesame seeds.[17*] The choices should be varied because binders in some plant foods may limit absorption.

Vitamin B_{12}

The requirement for vitamin B_{12} is small, but this vitamin is found only in animal-derived foods. Fermented soy products such as tempeh may contain some vitamin B_{12} from the bacteria that did the fermenting, but unfortunately, much of the vitamin B_{12} found in these products may be an inactive form. Seaweeds such as nori and chlorella supply some vitamin B_{12}, but not much, and excessive intakes can lead to iodine toxicity.[18] To defend against vitamin B_{12} deficiency, vegans must rely on vitamin B_{12}-fortified sources (such as soy milk or breakfast cereals) or supplements.

Vitamin D

For people who do not use vitamin D–fortified milk and do not receive enough exposure to sunlight to synthesize adequate vitamin D, supplements may be warranted. This is particularly important for children and older adults. In northern climates during winter months, young children on vegan diets can readily develop rickets, the vitamin D–deficiency disease.

As you can see, vegetarianism is not a religion like Buddhism or Hinduism, but merely an eating plan that selects plant foods to deliver needed nutrients. The quality of the diet depends not on whether it includes meat, but on whether the food choices are nutritionally sound. Health experts would quickly add that one should also limit intakes of substances such as fat and alcohol that are harmful in excess—and vegetarians in North America typically do. Interestingly, the Mediterranean diet—a predominantly vegetarian diet with an ethnic flair—breaks these rules on moderation, yet still seems to have health advantages.

An Almost-Vegetarian Diet: The Mediterranean Diet

Coastal populations that share the bounty of the Mediterranean waters may also share some important health advantages: The incidence of chronic diseases is low and life expectancy is high.[19] While popular sources report the marvels of the "Mediterranean diet," scientists who have attempted to define that diet or its health benefits have run into problems. One problem is that many countries border the Mediterranean Sea: Italy, Spain, Portugal, France, Greece, Syria, Lebanon, Israel, Turkey, Egypt, Algeria, and more. Consequently, there is no single "Mediterranean diet." Also, some of the data backing claims about causes of death in Mediterranean countries were collected in the 1960s, when the majority of people still consumed traditional diets. Even with these limitations, the links between Mediterranean diets and health are worth pondering.

Although each of the many countries that border the Mediterranean Sea has its own culture, traditions, and dietary habits, similarities are also evident.[20] The people dine on crusty breads, grains, potatoes, and pastas; a variety of vegetables and legumes; feta and mozzarella cheeses and yogurt; and fruit (especially grapes and figs).[21] They eat some fish, other seafood, and poultry, a few eggs, and very little meat. Their principal source of fat is olive oil, and they typically drink wine with meals. Consequently, traditional Mediterranean diets are:[22]

- Low in saturated fat.
- Rich in monounsaturated fat.

*Calcium salts are often added during processing to coagulate the tofu.

The people of the Mediterranean area eat plenty of fruits, vegetables, legumes, and grains; some dairy products, fish, and poultry; and very little red meat. Olive oil is their principal source of dietary fat.

- Rich in carbohydrate and fiber.
- Rich in nutrients and nonnutrients that support good health.

Furthermore, because processed foods are used modestly, intakes of salt, refined sugars, and *trans*-fatty acids are low.[23] All in all, the Mediterranean diet has gained a reputation for its health benefits as well as its delicious flavors.[24]

The Mediterranean Diet Pyramid

A few nutrition experts were so impressed with the Mediterranean diet and its health benefits that they created a renegade food pyramid.* Like the official USDA Food Guide Pyramid introduced in Chapter 2, their pyramid is based on breads, cereals, rice, pasta, and other grains, and it places vegetables and fruits on the next level up. The Mediterranean pyramid introduces a small difference at this level in that it includes legumes with the vegetable group instead of with the meats, but greater differences become apparent farther up the pyramid. Olive oil sits just above the fruits, vegetables, and legumes, with cheese and yogurt above that; these foods are to be included daily. Fish, poultry, eggs, and sweets come next and are to be eaten a few times per week. Lean red meats sit at the tip of the pyramid, to be eaten only a few times per month. Figure H6-1 compares the two pyramids.

This Mediterranean pyramid contradicts many diet and health recommendations and is worth examining because it raises interesting issues. For example, although current dietary recommendations restrict fat to no more than 30 percent of daily kcalories, the traditional Mediterranean diet can deliver as much as 40 percent of a day's kcalories from fat. The Mediterranean plan does not restrict total fat, but it

*The Mediterranean diet pyramid was developed by the Harvard School of Public Health, the European office of the World Health Organization, and the Oldways Preservation & Exchange Trust in Boston.

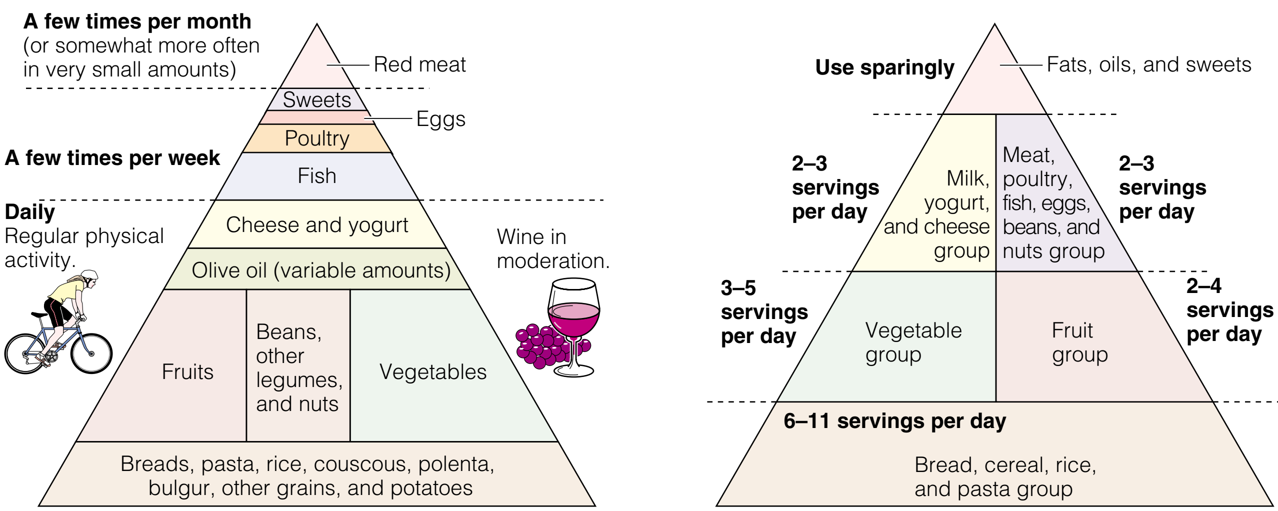
Figure H6–1
Food Pyramids Compared

Mediterranean Diet Pyramid

This pyramid is based on the dietary traditions of Crete around 1960, structured in light of current nutrition research.

USDA Pyramid

This pyramid is based on the dietary guidelines established in 1992 by the U.S. Department of Agriculture.



Sources: 1994 Oldways Preservation & Exchange Trust, U.S. Department of Agriculture.

does limit *animal* fat—a distinction not made in the USDA plan. People following the USDA plan get most of their fat from red meat, poultry, eggs, milk, yogurt, and cheese; consequently, much of their fat is saturated fat. Those following the Mediterranean plan use olive oil abundantly, and so receive most of their fat as monounsaturated vegetable oil. Their limited consumption of dairy products and meats provides less than 10 percent of their kcalories from saturated fats—a goal both plans agree on, but the USDA plan typically fails to meet.

The distinctions between types of fat have implications for chronic diseases, as Chapter 5 pointed out. The monounsaturated fats of olive oil and canola oil and the omega-3 polyunsaturated fats of fish may actually lower blood lipids and benefit heart health;[25] in contrast, most, but not all, saturated fats are detrimental. Substituting unsaturated fats such as olive oil for saturated fats or *trans*-fatty acids improves blood lipids and reduces the risks of cardiovascular disease.[26] In addition to its beneficial fatty acid composition (high in monounsaturated and low in saturated fatty acids), olive oil contains vitamin E and other antioxidant compounds that protect against heart disease.[27]

These distinctions in types of fat are not evident in the USDA pyramid and dietary recommendations. People are simply advised to cut back on all fat so that they will cut back on saturated fat—the primary suspect.

Many Mediterranean people drink wine with each meal, and the Mediterranean pyramid includes wine in moderation. Moderate alcohol consumption reduces the risk of cardiovascular disease and seems to be compatible with a healthy lifestyle.[28] The USDA pyramid does not address alcoholic beverages directly, but most diet and health recommendations advise people to drink alcoholic beverages in moderation, if at all.

Perhaps the hallmark of the Mediterranean diet is its abundance of vegetables, fruits, legumes, and whole grains—foods associated with lower risks of cardiovascular disease and cancer.[29] The protective effects of these plant-derived foods are attributed not only to their lack of fat, but also to their abundance of nutrients and nonnutrients, many of which act as antioxidants (see Highlight 11).

Some Concerns about the Mediterranean Plan

Critics of the Mediterranean plan have expressed concerns that it may be inadequate in calcium and iron—two problem nutrients for many people, especially women. Because these nutrients are typically lacking in many people's diets, it seems unwise to restrict calcium selections to cheeses and yogurt and iron-rich meat consumption to a few times a month.

An Implication of the Mediterranean Plan: Limit Meat

Is it appropriate to suggest that people in the United States should adopt Mediterranean eating habits and begin indulging in olive oil and wine? Not really, for at least two reasons. First, diet is not the only, or even the most important, factor implicated in disease causation, as Chapter 18 points out. Many other differences in the lifestyles of the people living in the Mediterranean and those living here could account for the differences in life expectancy and disease risks. Furthermore, as Highlight 2 pointed out, all ethnic food patterns have pros and cons. Perhaps the most important suggestion to be taken from the Mediterranean plan is to focus more on grains, vegetables, and fruits, and less on meats. On average, a person in the United States consumes more than half a pound of meat per *day;* a person in the Mediterranean region consumes about half a pound per *week*. The difference in meat intake, and therefore in saturated fat intake, is significant.

In general, at most, two 3-ounce servings of meat per day are needed. This amount of meat alone provides most of a person's daily recommended protein intake—and other foods together can provide a similar amount. Some researchers argue that this much meat eaten daily is not compatible with good health; if any meat is eaten, they suggest that it be eaten infrequently and in small portions.[30] With the evidence pointing to the health advantages of a meat-restricted diet, perhaps between 0 and 6 ounces of meat daily would best serve the needs of most people; the USDA pyramid suggests 5 to 7 ounces of meat, poultry, or fish a day.

Other Ethnic Pyramids

The Mediterranean pyramid was the first ethnic pyramid introduced by this group of nutrition educators, but it wasn't the last. Asian and Latin American pyramids have followed and an African-American pyramid is being developed.[31] Because the various sections of each pyramid reflect the culinary staples of its ethnic cuisine, the pyramids differ, but they share a common theme. Each emphasizes grains, vegetables, legumes, fruits, and oils daily; recommends eggs, milk products, fish, and poultry less frequently; and suggests beef and pork even less often.

Oldways Preservation & Exchange Trust
www.oldwayspt.org
Visit Food pyramids

Pyramids—Official and Otherwise

What about these renegade pyramids? It seems almost sacrilegious to oppose the government's official word on nutrition, but it can be enlightening to take a peek at the politics involved in developing such recommendations.

For more than a century, government agencies have issued statements advising consumers about food choices. Dietary guidelines may originally have been developed purely for the public good, but now they underlie national policy in many areas. They are used to define curricula for nutrition education, establish regulations for food labels, develop new food products, regulate institutional foodser-

vices, provide commodity foods, and create school menus. And because the guidelines encourage people to eat more of some foods and less of others, they exert a profound effect on food purchases. Inevitably, therefore, politics has become involved in the dietary guidelines.

Food producers did not complain when early dietary recommendations urged people to "Eat more" of their products to help prevent nutrient deficiencies. However, when recommendations began to urge people to "Eat less" of some products to help prevent chronic diseases, food producers became aroused. Now lobbyists representing the food industry scurry about Capitol Hill trying to protect their interests and influence national policies that affect dietary intakes. Their efforts have been successful.

The influence of the meat industry on government policy makers provides a notable example.[32] In 1977 a dietary goal was to "Decrease consumption of meat." The "Eat less" guideline was changed in 1980 to "Choose lean meat." By 1990 the recommendation was stated even more favorably, "Have two or three servings, with a daily total of about 6 ounces." By 1992, when the Food Guide Pyramid was created, the daily total had been revised to "5 to 7 ounces." The design of the pyramid itself was delayed by a year and cost an additional million dollars, in large part because of protests from the meat industry.

Two meat servings of the size depicted here represent the maximum daily meat intake suggested by the Daily Food Guide as health promoting.

The preceding paragraph was not written to pick on the meat industry. Lobbyists representing the dairy industry, the egg industry, the sugar industry, and every other food manufacturer try to influence dietary recommendations. The point is that people outside the world of nutrition science profoundly influence our nation's diet. Shifting our diet toward a healthier plan would require major changes in our agricultural and food manufacturing policies and practices.[33] One wonders what the government's nutrition advice would be if it were untainted by politics.

Having learned some of the relationships between diet and health, many people may discover that their strategies for planning meals need to change. In the past, they decided what cut of beef, ham, pork, lamb, poultry, or fish to prepare and then filled in the menu with an accompanying "starch" (potato, rice, or noodles), salad or other vegetable, and bread. Now they fill their dinner plates with legumes, grains, vegetables, and fruits. Then they add small quantities of milk products, eggs, lean meat, fish, or poultry.

For the most part, it seems that nonmeat and low-meat diets can both support good health. Keep in mind, too, that diet is only one factor influencing health. Whatever a diet consists of, its context is also important: no smoking; alcohol consumption in moderation, if at all; regular physical activity; adequate rest; and medical attention when needed all contribute to a healthy life. Establishing these healthy habits early in life seems to be the most important step one can take to reduce the risks of later diseases (as Highlight 16 explains).[34]

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